Dam Structure Characterization and Removal
Dams 11 Through 20

Turkey Creek
(Middle New River Watershed)
Monroe County, West Virginia

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POTESTA

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1.0 INTRODUCTION

Potesta & Associates, Inc. ("POTESTA") has been retained by Neely & Callaghan to provide professional environmental consulting services in the Turkey Creek watershed, Monroe County, West Virginia, as part of a Consent Decree (Civil Action No. 1:15-cv-16018) with the United States Environmental Protection Agency ("USEPA") (on behalf of the United States of America) and the State of West Virginia, by and through the West Virginia Department of Environmental Protection ("WVDEP"), regarding a complaint filed against James C. Justice Companies ("Justice Companies") and High Mountain Living, LLC for placement of dredged or fill material into "waters of the United States" without authorization from applicable state or Federal agencies. The intent of this document is to provide, in part, a conceptual restoration plan for Turkey Creek, specifically the characterization and removal of Dams 20, 19, 18, 17, 16, 15, 14, 13, 12 and 11 from Turkey Creek, for review and approval by the USEPA.

2.0 BACKGROUND

In January 2012, Justice Companies received an inspection report from the WVDEP involving the construction of several small dams along Turkey Creek. The report was generated as a result of a citizen complaint made to the WVDEP's Office of Environmental Enforcement. The inspection report indicated that the dams, located in Turkey Creek and an unnamed tributary of Turkey Creek, did not fall under jurisdiction of the Dam Control and Safety Act (W.Va. Code 22-14). Because the structures were not documented, this information was forwarded and, ultimately, brought to the attention of the USEPA and USACE. The USEPA is considered the lead federal agency in this matter.

As part of the Consent Decree, Justice Companies are required to complete restoration, mitigation, and preservation. This includes the submittal of a detailed restoration plan for the dams in Turkey Creek and an unnamed tributary of Turkey Creek. The restoration plan should address the following:

1. Designs to restore the dam locations to approximate pre-disturbance original conditions (or appropriate stable conditions) consistent with the definition of restoration found in 40 CFR § 23.92;
2. A schedule for implementation;

3. Compensation for impacts to streams and wetlands using the West Virginia Stream and Wetland Valuation Metric ("WVSWVM") to determine the appropriate amount of mitigation needed to offset permanent and temporal losses to aquatic resources;
4. Restoration to a stable configuration so that a channel and floodplain connection are maintained and excessive erosion, sedimentation, landslides or slips are avoided;
5. Utilization of only native West Virginia species for planting;
6. Qualitative performance measures;
7. Calculation of credit surplus (if any); and
8. Post-construction monitoring plan (10 years).

While the placement of dredge or fill material associated with each of the 20 dams in the Turkey Creek watershed was minimal, the restoration, mitigation, and preservation efforts are more complex as each structure has a unique set of conditions. Instead of one project, the restoration efforts are essentially 20 small projects in close proximity. As a result, the deliverable, a restoration plan, has been divided into three (3) individual documents that will address different components of an overall restoration plan. This document, *Dam Characterization and Removal, Dams 11 Through 20* (Volume I), provides information regarding the current conditions of Turkey Creek at Dam 11 through Dam 20 and represents the effort required to remove the structures in Turkey Creek, below the Turkey Creek wetland. Volume II will characterize and describe the removal of Dams 1 through 10 and Volume III will address the remaining items described above, including a determination of credits/debits using the WVSWVM.

3.0 PROJECT DESCRIPTION

The structures, Dams 11 through 20, are located in Turkey Creek between Willow Bend and McGlone, West Virginia. The proposed project is illustrated on the Union and Gap Mills, West Virginia United States Geologic Survey ("USGS") 7.5 minute quadrangle in Monroe County, West Virginia (**Figures 1 and 2 – Appendix A)**.

Each dam is individually assessed below. **Table 1** contains a list of dam locations along Lower Turkey Creek that were delineated and assessed for impacts to waters of the United States (**Figures 2A and 2B – Appendix A**). **Table 2** summarizes the widths, heights, drainage area, stationing, spacing, and status of each dam (Dams 20 through 11).

TABLE 1
Locations of Dams

Structure	(Latitude)	(Longitude)
Dam 20	37.53594	-80.50834
Dam 19	37.53429	-80.50745
Dam 18	37.53335	-80.50656
Dam 17	37.52987	-80.50443
Dam 16	37.52876	-80.50337
Dam 15	37.52731	-80.50155
Dam 14	37.52727	-80.50044
Dam 13	37.52683	-80.49970
Dam 12	37.52584	-80.49893
Dam 11	37.52490	-80.49823

TABLE 2
Turkey Creek Dam Summary

Dam	Width (Feet)	Height (Feet)	Length (Feet)	Stationing (Feet)	Drainage Area (Square Miles)	Failure
20	36.8	2.6	5	00+79 to 00+84	8.18	**Y**
19	37.7	3.8	5	07+13 to 07+18	8.15	**Y**
18	33.2	1.5	5	11+29 to 11+34	7.88	**Y**
17	33.9	3.6	6	24+20 to 24+26	7.75	**N**
16	29.4	2.9	5	28+18 to 28+23	7.74	**N**
15	42.2	2.7	5	34+17 to 34+22	7.03	**Y**
14	31	2.3	4	36+63 to 36+67	7.00	**Y**
13	33.9	3.2	4	38+48 to 38+52	6.99	**Y**
12	32.8	2.5	4	41+16 to 41+20	6.95	**N**
11	35.4	2.8	6	43+94 to 44+00	6.87	**Y**

4.0 WATERSHED INFORMATION

Turkey Creek flows 11,363 linear feet (2.15 river miles) downstream to its confluence with Indian Creek (050500020603) within the Middle New River Watershed (05050002) (**Figure 3 - Appendix A**). The study watershed, the drainage area above Dam 20, is approximately 8.18 square miles and is situated in the Valley and Ridge physiographic province. Please note that several sites for the Appalachian Plateau were established within the vicinity of Turkey Creek. Both regional curves were reviewed during the assessment of Turkey Creek. Based on geology and actual location within the Valley & Ridge physiographic province, POTESTA utilized the curve for that region. The Valley and Ridge province consists of elongated parallel ridges and valleys that are underlain by folded Paleozoic sedimentary rock. Karst is also common in the region (Keaton et al. 2005) as shown in **Figure 1** (**Appendix A**).

Natural Resources Conservation Service ("NRCS"), United States Department of Agriculture ("USDA"), and National Wetland Inventory ("NWI") data shows that, while there is presence of Udifluvents-Fluvaquents complex (floodplain soils) along much of the stream corridor, no NWI wetlands were identified (**Figure 4 - Appendix A**). While there was potential for wetland resources along the study reach, this report does not address potential pre-construction or post-construction wetland area.

Based on land use mapping, the study watershed (8.18 square miles or 5,235 acres) is composed of mixed land uses, primarily forests. The most predominant land cover was Southern and Central Appalachian Cove Forests. Southern and Central Appalachian Cove Forests consist of mesophytic hardwood or hemlock (**Figure 5 - Appendix A**). These cove forests are typically situated on concave slopes and have moist soil conditions. These systems also include acidic rich cove soils which were perceived in the field. Characteristic species include: *Aesculus flava*, *Acer saccharum*, *Fraxinus americana*, *Tilia americana*, *Liriodendron tulipifera*, *Halesia tetraptera*, *Tsuga canadensis*, *Fagus grandifolia*, and *Magnolia acuminata*. Other vegetation observed along the study area were *A.* flava, *A. saccharum*, *T. americana*, *L. tulipifera*, *T. canadensis*, *Fagus grandifolia*, *Polygala paucifolia*, *Aquilegia canadensis*, *Impatiens spp.*, *Hamamelis virginiana*, *Claytonia virginica*, *Smilax* spp., *Trillium grandiflorum*, *Viola rostrata*, *Asclepias* spp., *Lindera benzoin*, *Urtica dioica*, *Verbesina alternifolia*, *Juglans nigra*, and *Goodyera pubescens*.

5.0 GOALS AND OBJECTIVES

The dams evaluated in this document are very small structures (less than <2 meters) (Poff and Hart, 2002) and have a very limited storage volume potential. Much like run-of-river dams that historically have been used to raise the water level to create small reservoirs for water withdrawal, the dams in Turkey Creek were expected to have a very short residence time and observations found no control over release. The documented footprint of each structure was minimal, with the largest being 6 feet long, 42 feet wide, and less than 4 feet high (See **Table 2**). Regardless of size, any obstruction in a lotic system has the potential to impact instream and riparian conditions. Dams change the quantity and timing of downstream water flow, reduce the transport of alluvial materials and suspended sediments, and cause fragmentation of the stream corridor, interrupting downstream and upstream passage of biota (Braatne et al. 2008). While the structures in Turkey Creek were put in place to optimize trout habitat, an unintended consequence has been an actual loss in preferred habitat such as silt-free rocky substrate, 1:1 pool:riffle ratios, and well vegetated streambanks.

The primary purpose of this document is to describe the existing condition at each dam and provide conceptual plans for removal of each dam and stabilizing each reach (directly above and below each dam). Plans are conceptual in nature as final design decision will be made in the field using a modified design build approach. This is necessary as conditions found in this report may not be consistent with those present at the time of construction and onsite modifications may be necessary.

Because much of Turkey Creek was observed to be in a stable reference condition outside of the dam influence, POTESTA used the watershed conditions as the boundary condition to determine future stability of each reach. Due to the location of each dam, POTESTA also recommends a wetland inventory to prevent further impacts to potential wetlands resources.

The goal of the work described in this document is to restore Turkey Creek in the vicinity of Dams 11 through 20 to the conditions, as practicable, that were present prior to dam construction.

This would be accomplished by completing the following:

- Removing each dam structure (Dams 20 through 11).
- Stabilizing the dam abutment areas with grading and permanent vegetation.
- Stabilizing each backwater area utilizing potential grading and permanent vegetation.
- Revegetating temporary floodplain impacts associated with the access to each dam removal.
- Avoiding additional impacts to aquatic resources (wetland and stream).
- Monitoring physical changes in Turkey Creek (cross sections, longitudinal profiles, sieve analysis, riffle and pool particle distribution, and bank stability) before and after dam removal for up to one year, to determine if further stream restoration techniques are required for stabilization of each dam removal reach.
- Monitoring invasive species to prevent dominant and pervasive pest populations.
- Monitoring benthic macroinvertebrate communities and fish surveys to monitor existing and recovery conditions.

While an improvement in the success of native fisheries has not been incorporated as a goal or objective in this document, it should be noted that the intended consequence of dam construction was improving fish habitat. To that end, restoration efforts will, when practicable, incorporate measures that are known to improve fisheries.

As noted above, POTESTA is recommending the use of a modified design-build method. This is recommended as final design decisions can be made in the field. As a result, initial adaptive management efforts are real time which can improve the overall changes for restoration success. Additionally, this type of project management can be more cost effective allowing one to streamline the design process and communications with construction contractors.

6.0 DAM CHARACTERIZATION

POTESTA conducted longitudinal profiles and cross sections in association with each dam within this section of Turkey Creek to identify potential dam influence, dam failure, and to document the current condition of the channel upstream and downstream of the associated dam structure. At each dam, the longitudinal profiles reach ranged from the nearest stable riffle habitat upstream of the dam structure to the first riffle downstream of each dam. As a result, the length of the reach associated with each dam varied based on instream condition. For example, the reach (Reach 20) at Dam 20 was 238, while Reach 19 was 174 feet. In addition, four (4) cross sections were situated within each longitudinal profile to determine potential bankfull elevations and slopes. POTESTA identified localized degradation (scour pool) and aggradation in riffles downstream of each dam structure. Some bar formation downstream of each dam was also noted. Channel bottom morphology upstream of the dam or within the backwater were largely nondescript areas with pools and glides and varied levels of sedimentation and embeddedness due to different levels of dam failure. Riffle and run facets were difficult to discern due to backwater conditions.

The valley types were determined for the study area. The study area transitions from an alluvial fill valley to an alluvial gulch fill valley. Alluvial valleys have well developed floodplains. From Station 00+00 to Station 16+00 (Reaches 20, 19, and 18), Turkey Creek flows through moderate to wide valleys with relatively steep side slopes (**Figure 6 – Appendix A**). Above Station 16+00, Reaches 16, 13, 12, and 11 are positioned within a more narrow and confined valley with steep side slope. Reaches 17, 15, and 14 are situated at more confined points in the alluvial gulch valley with moderate bedrock influence.

The valley floor was gently sloping, as the average slope was generally less than 0.02. From Station 00+00 to 47+00, Turkey Creek was classified as a Bc to C type channel (**Figures 7 through 10 - Appendix A**). The classification riffles at Dam 20, 17, and 16 were F channels, however, with a 0.05 to 0.17 (Dam 20 and 17, respectively) adjustment for entrenchment, these reaches would be classified as Bc channel types. Classification of riffles at Dam 14, 15, and 13 indicates that Turkey Creek in these reaches were C channels with entrenchment ratios ranging from 2.74 to 3.66. Riffles at Dam 19, 18, 15, and 11 were classified as Bc channels. Overall entrenchment ratios ranged from 1.23 to 3.66. Width/depth ratios were greater than 12 as would be expected in B type channels.

Bank height ratio (“BHR”) was measured to determine the degree of channel incision. BHRs were generally low to very low; however, the riffle cross section associated with Dams 13, 14 and 16 were moderate. Moderate BHRs at each of these locations indicate incision (downcutting) and the stream banks in these regions are contributing higher amounts of sediment. While these areas are isolated, some vertical instability was noted. The moderate BHRs may also indicate that this portion of Turkey Creek at is at risk for decreased floodplain connectivity. The riffle at Dam 16 was transitioning from a Bc channel type to an F type channel. Classification of stream type at Dams 13 and 14 reflect C channel types and were considered entrenched.

In addition to the mainstem of Turkey Creek, POTESTA surveyed secondary channels (historic and recently developed) if these features were present in the riffle cross section downstream of each dam. In some instances, the secondary channels were historic; however, at Dam 12 this feature was a more recent development and present at flows below bankfull. As a result, the study reach at Dam 12 is at risk for avulsion.

Data collection began downstream of Dam 20 and proceeded upstream through Dam 11. Stationing is used to describe dam spacing and proximity in Turkey Creek; however, detailed data was only collected in the dam reaches. Cross sections were surveyed in a pool upstream of each dam (XS1 – Pool), across each actual dam (XS2 – Dam), the scour pool below each dam (XS3 – Scour Pool), and the riffle downstream of each dam (XS4 – Riffle) within each longitudinal profile survey. In some instances, best professional judgment ("BPJ") was utilized to determine the bankfull elevation and slope. Right bank in this document refers to right descending bank ("RDB") and the left bank is the left descending bank ("LDB").

As noted above, the conditions described in this document are those present in the summer of 2015, and may not be consistent with the conditions found at these sites prior to construction. Therefore, POTESTA recommends these sites be reevaluated just prior to dam removal.

6.1 Dam 20

Dam 20, the first structure in Turkey Creek (downstream to upstream), was located at Station 00+79 to 00+84 (**Figures 6, 7, and 8 – Appendix A**). POTESTA surveyed 238 feet of channel, including the backwater area behind Dam 20 (Reach 20). The riparian corridor on the RDB adjacent to Dam 20 had been disturbed and was dominated by shrubs and grasses (**Photo 1 – Appendix L**). Reach 20 was relatively straight (**Photos 2, 3, 4 and 5**). Dam 20 was located 629 feet downstream of Dam 19.

When evaluated in Spring 2015, the dam was 36.8 feet wide and 2.6 feet high **(Table 3)**. Dam height was measured from the toe of the structure. The dam face was five feet across. POTESTA noted that Dam 20 was constructed such that the elevation of the structure was situated just below the original bankfull depth.

The bankfull slope was estimated at 0.0092 while the water surface slope was lower (0.0078). The channel slope was measured at 0.0073, similar to that of the existing water slope (**Figure 1 – Appendix B**). Riffles, run, pool, and glide facets were discernible on the longitudinal profile (**Figure 1 – Appendix B)**.

Figure 2 (**Appendix B**) depicts what the estimated channel slope, bankfull slope, and water surface slope are predicted to be upon the initial dam removal process. The change in channel slope was estimated at 0.00159 (0.159 percent). The minimal change in slope, the existing low slope, existing channel morphology, and overall stability throughout the reach is expected to result in minimal downcutting (Stanley et al. 2002). The dam fountain created a scour pool feature that will likely fill in as particles move through the reach. This feature was clearly visible during low-flow conditions (**Photo 6**). The bankfull width upstream of the dam (XS1 – Station

01+22) was 28.9 feet with a depth of 2.07 feet (bankfull area 59.8 square feet) (**Figure 3 – Appendix B**). Upon dam removal, it is expected that the cross-sectional area of the bankfull channel (formerly located in the backwater of the dam) will decrease (Stanley and et al 2002).

The foundation of Dam 20 failed (XS2 – Station 00+79 to Station 00+84). Irregularities were noted in the structure in April 2014 (**Photo 7**). Failure was documented in July 2014. Cross section also showed a right bank abutment failure (**Figure 4 – Appendix B**). The dam structure had become unstable with water flowing through and under the foundation of Dam 20 (**Figure 8** and **Figure 9 – Appendix B**). Due to this failure, stream flow converges upstream of the dam at a riffle and scours under the dam flowing through scour pool area below the dam (**Photos 8 and 9**). A vertical pressure gradient caused flow impinging against the upstream face of the dam to downwell, driving high-velocity water toward the bed upstream of the obstruction. This downward flow, together with flow accelerating around the edges of the obstruction, has initiated bed scour along its upstream edge. Flow separation upstream of the obstruction and over the lip of the scour hole has created a large-scale vortex close to the bed (Buffington et al. 2002).

The cross-sectional area of the scour pool at Station 00+69 was 99.5 square feet, almost double the cross-sectional area of the pool surveyed in XS1 upstream of the dam (**Figure 5 – Appendix B**). The riffle or XS4 (Station 00+45) had a bankfull width of 30.9 feet and a depth of 1.54 feet (bankfull area 47.6 square feet) (**Figure 6 – Appendix B**). The entrenchment ratio of 1.35 with a 20.08 width/depth ratio suggests that this portion of the study reach was an F channel. Please note, an acceptable range of adjustment for entrenchment is 0.05. With an adjustment, this reach would be classified as a Bc channel type. While this would be considered appropriate for classification purposes, POTESTA believes that decreased entrenchment ratio may reflect a potential successional shift occurring in this reach which may result in less stable channel configuration if Dam 20 were left in place.

Using the Ridge and Valley regional curve for streams with a drainage area of 8.18 square miles (**Figure 7 – Appendix B**), bankfull width ranges from 28.09 to 35.03 feet for width, 1.59 to 2.07 feet for mean depth, and 53.78 to 60.64 square feet for cross-sectional area (**Table 4**). Based on this comparison of XS4 (riffle) and the regional curve, the reach was slightly smaller than the Ridge and Valley curve suggests (**Figure 7 – Appendix B**). These smaller dimensions may be representative of stable conditions in Turkey Creek; however, it is possible the riffle downstream of the dam has minimally aggraded.

Upstream and downstream views of the dam are shown in photographs on **Figure 8 (Appendix B)**. Stable banks and vegetative cover were observed immediately upstream of the dam. The substrate upstream of the dam was not homogenous as might be expected upstream of a dam structure. The right bank abutment failure, foundation failure, and scour area are shown on **Figure 9 (Appendix B)**. The right bank failure has been attributed to the flow accelerating around the edges of the dam during high-flow events that were above the bankfull flow (Cherry and Beschta, 1989). Large woody debris was present in the floodplain as well as on top of the dam and trapped upstream of the dam. Backwater influence or sedimentation upstream of the dam was minor. Further, bank stability and vegetative protection remains intact.

A document discussing dam removal was previously submitted to the USEPA (*Report Detailing Removal of Twenty Impounding Structures on Turkey Creek, Monroe County, West Virginia*). As noted in this document, POTESTA has recommended the structures in Turkey Creek be removed using minimally invasive techniques. Measurements taken upstream of Dam 20 indicate Turkey Creek were consistent with the Ridge and Valley curve indicating that the reach is stable. The reach is relatively straight and, when stream measurements were taken in 2015, the flow in Turkey Creek at Dam 20 was directed towards the center of the channel. If conditions are similar during restoration efforts, this reach of Turkey Creek will not require work instream other than removal of the dam. The dam should be removed such that the release of any sediment is done in a controlled manner. The banks at Dam 20 should be vegetated and stabilized as necessary. The riparian corridor should also be enhanced or reestablished as necessary.

Once Dam 20 is removed, it is expected that the fine sediment (silts) should be easily mobilized by channel flow. The channel should be able to overflow its banks and, during flood events, both fines and woody debris would be deposited in the floodplain.

Table 3
Dam 20 Measurements

Dam	Width (Feet)	Height (Feet)	Length (Feet)	Stationing (Feet)	Drainage Area (Square Miles)	Failure
20	36.8	2.6	5	00+79 to 00+84	8.18	Y

TABLE 4
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				**Ridge and Valley Province Reference**		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	47.6	30.9	1.54	53.78 - 60.64	28.09 – 35.03	1.59 - 2.07

6.2 Dam 19

Dam 19 was located at Station 07+13 to 07+18 (**Figures 7** and **8** – **Appendix A**). POTESTA surveyed 274 feet of channel, including the backwater area behind Dam 19 (Reach 19) (**Photo 10 – Appendix L**). Dam 19 was located 411 linear feet downstream of Dam 18.

When surveyed, the dam was 37.7 feet wide and 3.8 feet high (**Table 5**). POTESTA noted that Dam 19 was constructed with the elevation of the dam at or just below bankfull depth (**Photo 11**). The width of the dam face was five feet across.

The bankfull slope was estimated at 0.0126, while the water surface slope was lower (0.0115). The channel slope was measured at 0.0123 and was similar to that of the existing bankfull slope (**Figure 1 – Appendix C**). While the profile began at an upstream stable riffle, the backwater portion of the reach was less defined and attributed to sediment deposition and slack water conditions; therefore, riffle, run, pool, and glide facets were less discernible on the longitudinal profile (**Figure 1 – Appendix C**).

Figure 2 (**Appendix C**) depicts what the estimated channel slope, bankfull slope, and water surface slope are predicted to be upon the initial dam removal process. The change in channel slope is estimated at 0.0003 (0.03 percent). Because the change in slope is minor and the overall slope is low, problematic downcutting is not anticipated (the reach downstream of Dam 19 should be specifically monitored for downcutting). The scour pool below the dam will likely fill in as particles move through the reach.

The bankfull width upstream of the dam (XS1 – Station 07+29) was 52.3 feet with a depth of 1.26 feet (bankfull area 66 square feet) (**Figure 3 – Appendix C**). It is likely, based upon cross- sectional area and width and depth ratio, that XS1 has aggraded due to sediment deposition and increased embeddedness related to the placement of Dam 19 (**Photo 12**). However, beaver activity and large woody debris were noted upstream of the dam. Is it unclear if the debris was deposited during flooding or if the beaver dam had become abandoned. Upon dam removal, it is expected that the cross-sectional area of the bankfull channel (formerly located in the backwater of the dam) will decrease (Stanley et al. 2002).

While there was no foundation failure at Dam 19 (XS2 – Station 07+13 to 07+18) (**Photo 13**), POTESTA surveyed right bank and left bank abutment failures (**Figure 4 – Appendix C**). The dam structure had become unstable with water flowing around each side of the structure. Lateral instability due to flow accelerating around the edges of the dam (**Photo 14**) and increased channel widths were observed immediately upstream and downstream of Dam 19. The flow spilling over the U-shaped dam produced a converging jet that scours the bed below the dam (Buffington et al. 2002). Like Dam 20, the cross-sectional area of the scour pool below Dam 19, XS3 (Station 06+99), was approximately 110.7 square feet (**Figure 5 – Appendix C**), almost double the cross-sectional area of the pool surveyed in XS1 (Station 07+29) upstream of the dam. The riffle or XS4 (Station 06+79) had a bankfull width of 34 feet and a depth of 1.65 feet (bankfull area 56 square feet) (**Figure 6 – Appendix C**). The entrenchment ratio of 1.4 with a width/depth ratio of 20.16 (moderate) suggests that this portion of the study reach was a Bc channel.

Using the Ridge and Valley regional curve for streams with a drainage area of 8.15 square miles (**Figure 7 – Appendix C**), bankfull width ranged from 28.04 to 34.98 feet for width, 1.59 to 2.07 feet for mean depth, and 53.66 to 60.50 square feet for cross-sectional area (**Table 6**). Based on the comparison of XS4 (riffle) and the regional curve, the study reach dimensions downstream of Dam 19 fall within the value ranges predicted by the Ridge and Valley curve (**Figure 7 – Appendix C**). The dimensions upstream of the dam indicate the stream was overly wide.

The upstream view of the dam is shown on **Figure 8 (Appendix C)** and appears to have stable vegetation and stable banks. While the same was true for the downstream view, increased near bank stress downstream of the dam has contributed to bank erosion along the left bank (**Photos 15, 16, 17,** and **18**). This near bank stress may be attributed to vertical obstruction (boulder and tree) located within the channel. The substrate upstream of the dam was a mixture of gravel, cobble, boulder, and silt (**Photo 12**). The right and left bank abutment failures are shown on **Figure 9 (Appendix C)**. The right bank failure was attributed to the high flows (greater than bankfull) accelerating around the edges of the dam (Cherry and Beschta, 1989).

Removal of Dam 19 should be completed with a minimally invasive effort on the right bank. The structure should be removed in a manner that would allow for the controlled release of the waters behind the dam. The flow at this location was directed towards the center of the channel below the dam when Reach 19 was evaluated; however, the erosion along the left bank presents some concern and should be monitored. Additionally, POTESTA recommends that this reach be reevaluated prior to construction to determine if the direction of flow has not moved during the winter months. If the current configuration is maintained, POTESTA would not recommend the placement of structures in this reach at this time; however, banks will require vegetation and stabilization measures.

Large woody debris was present in the floodplain and within the channel upstream of the dam indicates that the channel still was accessing the floodplain. Backwater influence or sedimentation upstream of the dam was moderate making the determination of preconstruction stream facets difficult to discern and would be considered over widened. Once Dam 19 is removed, it is expected that the fine sediment (silts) will be easily mobilized by channel flow. It is also anticipated that during flood events both fines and woody debris would be deposited in the floodplain. Post construction, this location should be monitored after the first few storm events to evaluate the ongoing erosion on the left bank below the dam. If erosion rates are accelerated, remedial measures will be necessary. This may include instream structures to divert flow away from the left bank.

Table 5

Dam 19 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Spacing	Failure
19	37.7	3.8	5	07+13 to 07+18	8.15	629	Y

TABLE 6

Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				Ridge and Valley Province Reference		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	55.6	33.5	1.66	53.66 - 60.50	28.04 – 34.98	1.59 - 2.07

6.3 Dam 18

Dam 18 was located at Station 11+29 to 11+34 (5 linear feet) (**Figures 7** and **8 – Appendix A**). POTESTA surveyed 283 feet of channel including the backwater behind Dam 18 (Reach 18). Dam 18 was located 1,286 linear feet downstream of Dam 17. Dam 18 was constructed on a bedrock shelf or ledge **Photos 19, 20, 21, and 22** (**Appendix L**).

The dam was 33.2 feet wide and 1.5 feet high (**Table 7**). Dam height was measured from the toe. POTESTA noted that the dam was constructed such that the elevation was positioned just above bankfull depth. The width of the dam face was five feet across and the footprint of the structure in Turkey Creek was 166 ft^2.

The bankfull slope was estimated at 0.0173 while the water surface slope was 0.0166. The channel slope was measured at 0.01397, was lower than the existing bankfull slope (**Figure 1 – Appendix D**). While the profile began at an upstream stable riffle, a small portion of the reach was less defined and was attributed to sediment deposition and slack water conditions; therefore, riffle, run, pool, and glide facets were less discernible in this portion of the longitudinal profile (**Figure 1 – Appendix D**). However, a noteable pool was documented near Station 12+50.

Figure 2 (**Appendix D**) depicts what the estimated channel slope, bankfull slope, and water surface slope prediction upon the initial dam removal process. The change in channel slope was estimated at 0.00041 (0.041 percent). Downcutting is not anticipated as the dam was constructed on a bedrock shelf or ledge, i.e., bedrock controlled.

The width upstream of the dam (XS1 - Station 11+53) was 40.6 feet with a depth of 1.33 feet (bankfull area 54 square feet) (**Figure 3 – Appendix D**). Based upon cross-sectional area and width and depth ratio, it appears that XS1 has aggraded due to sediment deposition and increased embeddedness related to the placement of Dam 18 (**Photo 23**). Upon dam removal, it is expected that the cross-sectional area of the bankfull channel (formerly located in the backwater of the dam) will decrease.

While there was no foundation failure at Dam 18 (XS2 – Station 11+29 to 11+34) (**Figure 4 – Appendix D**), POTESTA surveyed a left bank abutment failure. The dam structure had become unstable with water flowing around the left descending abutment (**Photos 24, 25**, and **26**). Lateral instability due to flow accelerating around the edge of the dam and increased channel width were observed immediately upstream Dam 18. During low flow, the water only moved around the left bank abutment and did not spill over the top of the dam (**Figure 9 – Appendix D**). It also appeared that the pipes located in the base (**Photo 27**) where not discharging during low flow. It is important to note the channel was bedrock controlled at this dam and at the downstream pool cross section. The cross-sectional area of the scour pool, XS3 (**Figure 5 – Appendix D**), was approximately 118.3 square feet (Station 10+91), more than double the cross-sectional area of the pool surveyed in XS1 upstream of the dam; however, this feature may be a natural pool. The riffle or XS4 (Station 10+48) had a bankfull width of 37.7 feet and a depth of 1.52 feet (bankfull area 57.1 square feet) (**Figure 6 – Appendix D**). The entrenchment ratio of 1.64 with a width/depth ratio of 24.79 (moderate) suggests that this portion of the study reach was a Bc channel.

Using the Ridge and Valley regional curve for streams with a drainage area of 7.88 square miles (**Figure 7 – Appendix D**), bankfull width ranges from 27.63 to 34.45 feet for width, 1.57 to 2.05 feet for mean depth, and 52.36 to 59.04 square feet for cross-sectional area (**Table 8**). Based on the comparison of XS4 (riffle) and the regional curve, the reach downstream of Dam 18 falls within the value ranges of some of the measures predicted by the Ridge and Valley curve (**Figure 7 – Appendix D**).

The upstream and downstream views of the dam are shown on **Figure 8 (Appendix D)** and appeared to have stable vegetation and stable banks. The substrate upstream of the dam was silt, gravel, cobble, and boulder. The left bank abutment failure is shown on **Figure 9 (Appendix D)**. The left bank failure was attributed to the high flows (greater than bankfull) accelerating around the edges of the dam.

Backwater influence or sedimentation upstream of the dam was minor. This may be the result of the dam abutment failure. Trout were observed feeding during the morning survey in 2015. Stream dimension or bankfull measurements upstream of the dam were not consistent with the Ridge and Valley curve and would be considered slightly widened. Once Dam 18 is removed, it is expected that the fine sediment (silts) will be easily mobilized by channel flow. During flood events, both fines and woody debris would be deposited in the floodplain. A substantial amount of woody debris was noted on the dam and downstream of the dam (**Photos 24**, **25**, **28**, and **29**). This was attributed to beaver activity in the watershed.

Removal of Dam 18 should be completed on the RDB. Care should be taken when removing this structure; efforts should be made to avoid releasing waters that would be directed towards the left bank abutment failure. There is concern that the channel will not align towards the center of the channel, therefore, POTESTA strongly recommends this reach be reevaluated prior to construction to determine if the direction of flow has not moved during the winter. When surveyed in 2015, there was a large pool on the right bank at Station 11+53. The presence of the pool can be observed in **Photos 23** and **27**, during low-flow conditions. In less than 30 feet, the bulk of the flow is directed towards the left bank and the abutment failure. When the structure is removed, it is hoped that flow will redirect itself towards the center of the channel. The base of the dam and the portion of the reach at the structure are believed to be partially bedrock controlled; however, this cannot be verified due to the amount of material accumulated behind the dam. This material is not soft sediments, as would be expected behind a small structure, but a hard packed mixture of smaller particulate matter, cobble and gravel.

Restoration efforts should include work to re-establish the left bank. This may include measures like root wads, to protect the bank and deflect the flow. No instream structures are recommended at this time. However, the reach will need to be observed during dam removal and potentially the next bankfull event to determine if flow has moved away from the left bank. If conditions warrant, instream measures may be required.

Table 7
Dam 18 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Spacing	Failure
18	33.2	1.5	5	11+29 to 11+34	7.88	411	Y

TABLE 8
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				Ridge and Valley Province Reference		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	57.1	37.7	1.52	52.36 – 59.04	27.63 – 34.45	1.57 - 2.05

6.4 Station 12+36 Ford

There was a ford in Turkey Creek at Station 12+36 (**Photos 30**, **31**, and **32 – Appendix L**) to allow access to a barn on the left bank (**Photos 33** and **34**).

6.5 Station 23+33 Ford

There was a ford in Turkey Creek at Station 23+33 that current and historic (1971) mapping describe as part of a Jeep Trail (**Photos 35** and **36 – Appendix L**). The ford, which was partially composed of large bedrock, boulder, cobble, and gravel (**Photo 37**), was likely used during dam construction for access to the left bank as between Dam 16 and Dam 17, the floodplain on the right bank becomes more steep and no longer provides access to Turkey Creek (**Photo 38**).

6.6 Dam 17

Dam 17 was situated at Station 24+20 to 24+26 (6 linear feet) (**Figures 7** and **9 – Appendix A**). POTESTA surveyed 309 linear feet of channel, including the backwater area behind Dam 17 (Reach 17) (**Photo 39 – Appendix L**). Dam 17 was located 392 feet downstream of Dam 16.

The dam was 33.9 feet wide and 3.6 feet high (**Table 9**). The dam was six feet long and the footprint of the structure in Turkey Creek was 203.4 square feet (**Photos 40** and **41**).

The bankfull slope was estimated at 0.0131 while the water surface slope was slightly higher (0.0154). The channel slope was measured at 0.0156 which was higher than the existing bankfull slope (0.0131) or water surface slope (**Figure 1 – Appendix E**). Riffle and run facets were discernible on the longitudinal profile (**Figure 1 – Appendix E**). Based on BPJ, this reach may not have contained pool or glide facets and resembled a plane-bed stream (Montgomery &

Buffington, 1997). The only pools noted within the reach were associated with the dam and would be considered forced pools. The profile began at an upstream stable riffle; however, the portion of the reach upstream of the dam was less defined.

Figure 2 (Appendix E) depicts what the estimated channel slope, bankfull slope, and water surface slope predicted upon the initial dam removal process. The change in channel slope was estimated at 0.0002 (0.02 percent). Due to low slope change and overall stability throughout the reach, this reach should not contribute to downcutting upon removal of the dam. A small scour pool was located below the dam.

The current bankfull width upstream of the dam (XS1 – Station 24+30) was 39.5 feet with a depth of 1.61 feet (bankfull area 63.5 square feet) (**Figure 3 – Appendix E**). Based upon cross sectional area and width and depth ratio of XS1, this section of the reach had aggraded and over widened due to the placement of Dam 17. Trees once located above bankfull elevation were located within the wetted width of the channel (below the current bankfull location elevation) upstream the dam (**Photos 42**, **43,** and **44**).

There was no foundation failure or abutment failure at Dam 17 (XS2 – Station 24+20 to 24+26) (**Photos 47** and **48**) (**Figure 4** – **Appendix E**); however, it is anticipated that the overly wide channel will eventually contribute to abutment failure due to flow accelerating around the edge of the dam (**Photos 45** and **46**). The cross-sectional area of the scour pool was approximately 79.7 square feet (XS3 - Station 24+05) (**Figure 5** – **Appendix E**), which was comparable to the cross-sectional area of the pool surveyed in XS1 upstream of the dam (63.5 square feet). The riffle or XS4 (Station 23+59) had a bankfull width of 37.3 feet and a depth of 1.49 feet (bankfull area 55.4 square feet) (**Figure 6 – Appendix E**). The entrenchment ratio of 1.23 with a 25.04 width/depth ratio suggests that this portion of the study reach was an F channel. An acceptable range of adjustment for entrenchment is 0.17 (up to 0.20). With an adjustment, this reach would be classified as a B to Bc channel type. While this approach would be considered appropriate for classification purposes, POTESTA believes that decreased entrenchment ratio may reflect a potential successional shift to a less stable channel configuration if Dam 17 were left in place.

Using the Ridge and Valley regional curve for streams with a drainage area of 7.75 square miles (**Figure 7 – Appendix E**) bankfull width ranges from 27.44 to 34.22 feet for width, 1.57 to 2.03 feet for mean depth, and 51.76 to 58.36 square feet for cross-sectional area (**Table 10**). Based on the comparison of XS4 (riffle) and the regional curve, the downstream reach falls within the value ranges predicted by the Ridge and Valley curve (**Figure 7 – Appendix E**). Upstream of Dam 17 channel was slightly wider and shallower than the regional curve indicates indicating potential aggradation.

The upstream and downstream views of the dam are shown on **Figure 8 (Appendix E)**. Stable vegetation was observed in the downstream view; however, the upstream vegetation along the lower portions of the floodplain in Reach 17 had become inundated (**Photos 42**, **43** and **44**). Due to these conditions, bank stability and vegetative cover was poor upstream of the dam. The substrate upstream of the dam was a mixture of silt and embedded gravel, cobble, and boulder. Piping was observed in the foundation of the structure **Figure 9 (Appendix E)**. Moderate amounts of large woody debris were noted in the floodplain behind the dam and on top of the structure (**Photos 49**, **50**, and **51**). Backwater influence or sedimentation upstream of the dam was moderate.

Stream dimension or bankfull measurements upstream of the dam were not consistent with the Ridge and Valley curve and would be considered widened. Upon dam removal, it is expected that the cross sectional area of the bankfull channel (formerly located in the backwater of the dam) will decrease. Some bar formation along the LDB was noted downstream of the dam. Once Dam 17 is removed, it is expected that the fine sediment (silts) will be mobilized by channel flow; however, successful vegetation establishment is vital to reducing the continued input of streambank erosion at the site. It appeared that Turkey Creek was still connected to the floodplain and, upon dam removal, during flood events both fines and woody debris would be deposited in the floodplain and be transported through the system.

Prior to dam removal, it is recommended that the conditions at Dam 17 be reevaluated. Dam removal should be completed on the left bank. Controlled release is recommended. The dam should be removed in a manner that does not apply undue pressure to the right or left bank and it may be that this dam should be notched in the center for slow release. It may also be necessary to plug the piping under the dam during dam removal. Additionally, the sediment deposition and embeddedness in the upstream portion of the Dam 17 study reach was extensive.

The areas currently located in the over widened and inundated sections of stream above the dam will need to be stabilized and permanently vegetated to prevent further lateral instability and mass bank erosion. Reach 17 was relatively straight and it is anticipated that, after dam removal, this reach will stabilize such that instream structures are not required. These conditions may change if pre-construction inspection finds that the abutments at Dam 17 have failed.

Table 9
Dam 17 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Failure
17	33.9	3.6	6	24+20 – 24+26	7.75	N

TABLE 10
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				Ridge and Valley Province Reference		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	57.4	37.3	1.49	51.76 – 58.36	27.44 – 34.22	1.57 - 2.03

6.7 Dam 16

Dam 16 was situated at Station 28+18 to 28+23 (5 linear feet) (**Figures 7 and 9 – Appendix A**). POTESTA surveyed 193 linear feet of channel, including the backwater area behind Dam 16 (Reach 16) (**Photos 52, 53,** and **54**). Dam 16 was located 594 linear feet downstream of Dam 15. It should be noted that, in the area downstream of Dam 16, several natural ledges or small hydraulic drops were noted instream (**Photos 55**, **56**, **57**, and **58**).

The dam was 29.4 feet wide and 2.9 feet high (**Table 11**). The length of the dam was five feet across and the footprint of the structure in Turkey Creek was 147 ft^2 (**Photos 59** and **60**). The dam face rises slightly on the left bank (**Photo 61**).

The bankfull slope was estimated at 0.0142 while the water surface slope was slightly steeper (0.0155). The channel slope was measured at 0.01565 (**Figure 1 – Appendix F**). Riffle and run facets were discernible on the longitudinal profile (**Figure 1 – Appendix F**). Based on best professional judgment, this reach may not have contained pool or glide facets and resembles a plane-bed stream (Montgomery & Buffington, 1997). The only pools noted within the reach were associated with the dam and would be considered forced pools. Sediment deposition was evident behind the face of the dam (**Photos 62** and **63**).

Figure 2 (**Appendix F**) depicts the estimated channel slope, bankfull slope, and water surface slope prediction upon the initial dam removal process. The change in channel slope was estimated at 0.0004 (0.04 percent). Due to predicted low slope change, existing channel morphology, and overall stability throughout the reach, downcutting upon removal of the dam is not anticipated. The bankfull width upstream of the dam (XS1 – Station 28+36) was 33.5 feet with a depth of 2.17 feet (bankfull area 72.9 square feet) (**Figure 3 – Appendix F**).

There was no foundation failure at Dam 16 (XS2 – Station 28+18 to 28+23) (**Figure 4 – Appendix F**); however, the right abutment appeared to be unstable and the area around the left bank abutment was degrading (**Photos 64, 65**, **66**, **67**, and **68**). The flow accelerating around the abutments of the dam during high-flow events (greater than bankfull) were eroding the LDB and RDB. This was likely compounded by the lack of vegetation and disturbance during construction. The dam also contained a pipe that appears to be capped (**Photo 63**).

The cross-sectional area of the scour pool, XS3 (Station 28+08) was approximately 80.1 square feet (**Figure 5 – Appendix F**), which was slightly larger than the cross-sectional area of the pool surveyed in XS1 upstream of the dam (72.9 square feet). The riffle or XS4 (Station 27+69) had a bankfull width of 29.5 feet and a depth of 1.69 feet (bankfull area 49.8 square feet) (**Figure 6 – Appendix F**). The entrenchment ratio of 1.32 with a 17.46 width/depth ratio suggests that this portion of the study reach was an F channel. An acceptable range of adjustment for entrenchment is 0.08. With an adjustment, this reach would be classified as a B to Bc channel type. While this would be considered appropriate for classification purposes, POTESTA believes that decreased entrenchment ratio may reflect successional shift to a less stable channel configuration if Dam 16 were left in place.

Using the Ridge and Valley regional curve for streams with a drainage area of 7.74 square miles (**Figure 7 – Appendix F**), bankfull width ranges from 27.41 to 34.19 feet for width, 1.57 to 2.03 feet for mean depth, and 51.69 to 58.29 square feet for cross-sectional area (**Table 12**). Based on the comparison of XS4 (riffle) and the regional curve, the width and depth dimensions fall within the value ranges predicted by the Ridge and Valley curve (**Figure 7 – Appendix F**). The channel area was slightly smaller than the regional curve indicates which may suggest potential aggradation. Bankfull indicators were difficult to discern at XS4 and BPJ was used as the cross section showed top of bank but no clear bankfull were identified.

The upstream and downstream views of the dam are shown on **Figure 8 (Appendix F)**. Stable vegetation was observed in the downstream view; however, the upstream vegetation along the lower portions of the floodplain had become slightly inundated. Due to these conditions, bank stability and vegetative cover was marginal upstream of the dam. The substrate upstream of the dam was silt, gravel, cobble, and boulder. Abutment failure was not pronounced but noted as potential with continued exposure to high flows (**Figure 9 - Appendix F)**.

Minor amounts of large woody debris were noted in the floodplain. Backwater influence or sedimentation upstream of the dam was moderate. Stream dimension or bankfull measurements upstream of the dam were not consistent with the Ridge and Valley curve and would be considered widened. Once Dam 16 is removed, it is expected that the fine sediment (silts) will be mobilized by channel flow. Turkey Creek was still connected to its floodplain in this reach. Upon dam removal, during flood events, both fines and woody debris would be deposited in the floodplain and be transported through the system.

Removal of Dam 16 should be completed with a minimally invasive effort on the left bank. Like the other structures, POTESTA recommends that this reach be reevaluated prior to construction. The structure should be removed so that flow is directed toward the center of the channel with a controlled release of water. While a small pool was located at the base of the dam, this reach contains few deep pools. Post-dam removal, it is expected that fine material will move rapidly from this reach. Banks along this reach will require vegetative and stabilization measures. Specific locations include the two abutments on each bank and areas in the bankwater that have been denuded due to inundation. Successful vegetation establishment is vital to reducing the continued input of streambank erosion at the site.

Table 11
Dam 16 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Failure
16	29.4	2.9	5	28+18 – 28+23	7.74	N

TABLE 12
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				**Ridge and Valley Province Reference**		
	A_{bkf}	**W_{bkf}**	**D_{bkf}**	**A_{bkf}**	**W_{bkf}**	**D_{bkf}**
XS4 - Riffle	49.85	29.51	1.69	51.76 – 58.36	27.44 – 34.22	1.57 - 2.03

6.8 Station 28+80 Tributary

An unnamed tributary of Turkey Creek was located at Station 28+80 (Photos **69**, **70**, and **71 – Appendix L**). This location corresponded to the end of the backwater area of Dam 16 (Photos **72**, 7**3**, and **74**). The tributary appeared to be non-impacted by construction activities in Turkey Creek and was believed to be intermittent in nature.

6.9 Dam 15

Dam 15 was situated at Station 34+17 to 34+22 (5 linear feet) (**Figures 7** and **9** - **Appendix A**) (**Photos 75**, **76**, and **77**). POTESTA surveyed 371 linear feet of channel, including the backwater area behind Dam 15 (Reach 15) (**Photo 78**, **79**, and **80**). Dam 15 was located 241 linear feet downstream of Dam 14.

The dam was 42.2 feet wide and 2.7 feet high (**Table 13**) (**Photos 81** and **82**). Dam height was measured from the toe on top of the bedrock ledge (**Photo 83**). POTESTA noted that the dam was constructed above the historic bankfull elevation at this location. The width of the dam face was five feet across and the footprint of the structure in Turkey Creek was 211 ft^2.

The bankfull slope was estimated at 0.0092 while the water surface slope was lower (0.0074). The channel slope was also measured at 0.0092 (**Figure 1 – Appendix G**). Riffle, run, pool and glide facets were discernible on the longitudinal profile (**Figure 1 – Appendix G**). The profile began at an upstream stable riffle; however, the upstream portion of the reach was less defined which was attributed to sediment deposition and backwater conditions.

Figure 2 (**Appendix G**) depicts what the estimated channel slope, bankfull slope, and water surface slope are predicted to be upon the initial dam removal process. The channel slope was not estimated to change; however, the bankfull channel slope and water surface will become more parallel upon dam removal. With no change in slope predicted and the bedrock control through the reach, minimal downcutting upon removal of the dam is anticipated. A scour pool was located below the dam and, while there is some potential for this feature to "fill in" as particles move through the reach, it is likely that the feature will maintain pool form as it is located below an existing rock ledge (**Photo 83).** The bankfull width upstream of the dam (XS1 – Station 34+37) was 41.4 feet with a depth of 2.19 feet (bankfull area 90.7 square feet) (**Figure 3 –Appendix G**).

There was no foundation or abutment failure at Dam 15 (XS2 – Station 34+17 to 34+22) (**Figure 4** – **Appendix G**) (**Photos 84** and **85**); however, beyond the left descending, an existing or historic access to McGlone Notch was noted. Specifically, the road that was noted below Dam 17 continues upstream on the left bank above Turkey Creek. Between Station 32+00 and Station 34+00, the valley becomes narrow and the road enters the creek bed (**Photos 86**, **87**, **88**, and **89**). There was a notable change in substrate in the potion of Turkey Creek that was utilized as roadbed. The road moves back on the LDB just downstream of Dam 15 with a small rise between the road and Turkey Creek. During high flows, it is likely that waters spill over into the access road at the left abutment.

As noted, Dam 15 was constructed above the historic bankfull elevation of Turkey Creek. The abutments and foundation of Dam 15 are stable due to the presence of bedrock control. Additionally, during high flows, the channel overflows into the historic road, taking the near bank stress off of the left abutment area (**Figure 9** – **Appendix G**). The cross-sectional area of the scour pool, XS3 (Station 34+08), was approximately 67.7 square feet (**Figure 5 – Appendix G**), which was smaller than the cross-sectional area of the pool surveyed in XS1 upstream of the dam (90.7 square feet). The riffle or XS4 (Station 33+85) had a bankfull width of 35.4 feet and a depth of 1.22 feet (bankfull area 43.3 square feet) (**Figure 6 – Appendix G**). The entrenchment ratio of 1.92 with a 29.04 width/depth ratio suggests that this portion of the study reach was classified as a B to Bc channel type. Limits were used on this cross section to reflect bankfull conditions on the mainstem.

Using the Ridge and Valley regional curve for streams with a drainage area of 7.03 square miles, bankfull width ranges from 26.27 to 32.77 feet for width, 1.52 to 1.98 feet for mean depth, and 48 to 54 square feet for cross-sectional area (**Table 14**). Based on the comparison of XS4 (riffle) and the regional curve, the reach downstream falls outside of the cross-sectional area range predicted by the Ridge and Valley curve (**Figure 7 – Appendix G)**). The channel was wider and shallower than the regional curve indicates and appeared to have aggraded.

The upstream and downstream views of the dam during the longitudinal survey are shown on **Figure 8 (Appendix G)**. Stable vegetation was observed in the downstream view; however, the upstream vegetation along the lower portions of the floodplain had become inundated. Due to the widened channel and decreased bank stability, vegetative cover was marginal to poor upstream of the dam (**Photos 90**, **91**, **92**, **93**, **94**, and **95**). The backwater area at Dam 15 was extensive and several dead trees were noted upstream of the dam and should be removed to prevent damming or channel blockage from large woody debris. Beaver activity was also noted from this section of Turkey Creek and continued upstream through Dam 11.

Where visible, the substrate upstream of the dam was silt, gravel, cobble, and boulder. Abutment failure was not noted, but overflow during storm events may discharge into the adjacent road on the left bank (**Figure 9 – Appendix G**). Backwater influence upstream of the dam was substantial and sedimentation was difficult to discern due to extensive large woody debris submerged in the backwater. Stream dimension or bankfull measurements upstream of the dam were not consistent with the Ridge and Valley curve and would be considered widened.

Once Dam 15 is removed, it is expected that the fine sediment (silts) will be mobilized by channel flow; however, successful vegetation establishment is vital to reducing the continued input of streambank erosion at the site. Dam removal should occur from the left bank; however, care must be taken to minimize impact to the small knoll that separates Turkey Creek from the adjacent road. If adequate height is not maintained, Turkey Creek will flow into the access road during bankfull events. Restoration efforts at this location should focus on establishment of vegetation and bank stability. Instream structures are not being recommended at this time. The reach has a substantial amount of bedrock and large shifts in flow direction are not anticipated. However, this reach should be re-evaluated prior to construction. As with most of the structures in Turkey Creek, high winter and spring flows have the potential to alter the existing channel conditions that may result in modifications to the recommendations found in this document.

Dead tree removal should also be considered during stabilization efforts. Based on the estimated BHR (1.00 – Very Low) at this location, during flood events both fines and woody debris would be deposited in the floodplain and be transported through the system.

Table 13
Dam 15 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Failure
15	42.2	2.7	5	34+17 – 34+22	7.03	N

TABLE 14
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				Ridge and Valley Province Reference		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	43.3	35.4	1.22	48.22 – 54.38	26.27 – 32.77	1.52 – 1.98

6.10 Road Crossing at Station 35+61

An existing and unmaintained road branching off of Turkey Creek Road was noted traversing the hillside along the RDB of Turkey Creek near Dam 14. This road crosses Turkey Creek at a Ford at Station 35+60, just upstream of the bank waters of Dam 15 (**Photos 96**, **97**, **98**, and **99 – Appendix L**). This ford will likely be utilized during restoration efforts.

6.11 Dam 14

Dam 14 was situated at Station 36+63 to 36+67 (4 linear feet) (**Figures 7** and **10 – Appendix A**) (**Photo 100 –Appendix L**). POTESTA surveyed 264 linear feet of channel, including the backwater area behind Dam 14 (**Photos 101** and **102**). Dam 14 was located 181 linear feet downstream of Dam 13.

The dam, which was composed of cut stone, field stone and cement, was 31 feet wide and 3.2 feet high (**Table 15**). Bankfull was difficult to determine at this location due to incision. The BHR within the riffle cross section was moderate (1.50). The width of the dam face was four feet across and the footprint of the structure in Turkey Creek was 124 ft^2 (**Photo 103**).

The bankfull slope was estimated at 0.0097 while the water surface slope was slightly lower (0.00834). The channel slope was measured at 0.01068, which was higher than the existing bankfull slope (**Figure 1 – Appendix H**). Riffle, run, pool and glide facets were discernible on the longitudinal profile (**Figure 1 – Appendix H**). The profile began at an upstream stable riffle; however, some of the upstream portions of the reach were less defined which was attributed to sediment deposition and backwater conditions.

Figure 2 (**Appendix H**) depicts the estimated channel slope, bankfull slope, and water surface slope prediction upon the initial dam removal process. The change in channel slope was estimated at 0.00054 (0.054 percent). Incision downstream of the dam removal should be moderate for active incision; however, extreme downcutting is not anticipated to continue downstream. The scour pool below the dam may fill in as particles from the depositional area behind the dam move through the reach.

The bankfull width upstream of the dam (XS1 – Station 36+88) was 36.2 feet with a depth of 1.74 feet (bankfull area 63 square feet) (**Figure 3 – Appendix H**). It is likely, based upon cross- sectional area and width and depth ratio that XS1 has aggraded and over widened due to the placement of Dam 14. Upon dam removal, it is expected that the cross-sectional area of the bankfull channel will decrease.

There were no foundation failures present at Dam 14 (XS2 – Station 36+63 to 36+67) (**Figures 4** and **8 – Appendix H**). A right bank abutment failure was developing (**Photos 104** and **105**) (**Figure 9 – Appendix H**). The channel upstream of the dam was over widened and will eventually result in abutment failure due to flow accelerating around the edge of the dam. The cross-sectional area of the scour pool, XS3 (Station 36+50), was approximately 105.2 square feet (**Figure 5 – Appendix H**), which was larger than the cross-sectional area of the pool surveyed in XS1 upstream of the dam (63 square feet).

An existing secondary floodplain channel was present at the site, as were other smaller channels that are assumed to be developing as the result of the placement of Dam 14 (**Photos 106 – 111**). Visual observations indicate that, during high-flow events, water was distributed across the floodplain and utilizing secondary channels. Channels may migrate naturally to dissipate energy and increase exchange of nutrient and material between aquatic and riparian habitats. While the smaller developing channels may carry flood waters during high-flow events, the older secondary channel shown in the dam and riffle cross sections likely demonstrates a more permanent flow (**Photos 108** and **109**). Water sources could include groundwater or hillslope contributions, particularly during wet months, precipitation, or may result from upwelling of waters from hydrostatic pressures resulting in changes in the water surface elevation of the mainstem. The secondary channel contributes to lateral stream channel complexity and resulting habitat diversity (Franssen et al. 2015). The channels will also transport materials and/or nutrients that have been deposited in the floodplain or are present in groundwater contributions.

The riffle or XS4 (Station 36+43) had a bankfull width of 28.3 feet and a depth of 1.82 feet (bankfull area 51.6 square feet) (**Figure 6** – **Appendix H**). The entrenchment ratio of 2.83 with a 15.55 width/depth ratio suggests that this portion of the study reach was a C channel. POTESTA believes that increased entrenchment ratio and decreased width/depth ratio may reflect a potential successional shift to a less stable channel configuration of C to Gc to F if Dam 14 were left in place (Rosgen 2006).

Using the Ridge and Valley regional curve for streams with a drainage area of 7.00 square miles, (**Figure 7 – Appendix H**) bankfull width ranges from 26.22 to 32.70 feet for width, 1.52 to 1.98 feet for mean depth, and 48.06 to 54.20 square feet for cross-sectional area (**Table 16**). Based on the comparison of XS4 (riffle) and the regional curve, the downstream reach dimensions fall within the range predicted by the Ridge and Valley curve (**Figure 7 – Appendix H**).

The areas located upstream of the dam were over widened and inundated sections of stream above the dam will need to be stabilized and permanently vegetated to prevent further lateral instability and mass bank erosion. Additionally, the sediment deposition and embeddedness in the upstream portion of the Dam 14 study reach was moderate (**Photos 112**, **113**, and **114**); however, beaver activity may have contributed to sediment deposition and fine/coarse woody debris upstream of the dam.

The upstream and downstream views of the dam are shown on **Figure 8 (Appendix H)**. Stable banks were observed in the upstream and downstream view with the exception of the areas directly upstream of Dam 14. The upstream vegetation along the lower portions of the floodplain adjacent to Dam 14 had become inundated and, due to these conditions, bank stability and vegetative cover was poor upstream of the dam. Vegetation and bank stability along the right bank at and below the dam abutment was protected by root wads; however, it is likely the banks will continue to erode around the cover (**Figure 9 – Appendix H)**.

Minor amounts of large woody debris were noted in the floodplain (**Photo 115**). Abundant amounts of coarse and fine woody debris from beaver activity was noted behind the dam (**Photos 112** and **113**). Backwater influence or sedimentation upstream of the dam was moderate (**Photo 114**). Stream dimension or bankfull measurements upstream of the dam were consistent with the Ridge and Valley curve.

Removal of Dam 14 should occur on the right bank. An existing and unmaintained road branching off of Turkey Creek Road was noted on the hillside along the RDB. It is likely that this access was used for the placement of some of the structures in Turkey Creek. Every effort should be made to utilize this same path for dam removal.

As noted, a secondary channel exists in the floodplain at Dam 14. This channel should be avoided so that it may maintain its connectivity with the mainstem channel. Newly developed secondary channels were also identified. These channels were poorly defined and relatively small and likely the result of the mainstem adjusting to backwater conditions associated with Dam 14. These newly developed channels should be regraded and vegetated post-dam removal to prevent further channel widening and mass erosion.

Dam removal should occur in a manner that places minimal stress on the RDB near the abutment failure. Current instream conditions indicate that, once the dam is removed, the channel should adjust to a more appropriate configuration without the need for instream structures. This should be verified prior to construction as high-flow events in the winter and spring could result in modifications along the right bank which would require more invasive restoration techniques.

Some bar formation along the LDB was noted downstream of the dam. Once Dam 14 is removed, it is expected that the fine sediment (silts) will be mobilized by channel flow; however, successful vegetation establishment is vital to reducing the continued input of streambank erosion at the site. As a result, it is recommended that Dam 14 restoration efforts focus on vegetative and bank stabilization measures.

The BHR at this location puts the site at moderate risk; however, it is anticipated that, post-dam removal, during flood events both fines and woody debris would be deposited in the floodplain and be transported through the system. Limits were used on this cross section to reflect bankfull conditions on the mainstem. As previously noted, a historic secondary channel was noted along the right descending bank which rejoins the mainstem downstream of the longitudinal profile.

Table 15
Dam 14 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Failure
14	31	2.3	4	36+63 – 36+67	7.00	Y

TABLE 16
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				Ridge and Valley Province Reference		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	51.6	28.30	1.82	48.06-54.20	26.22-32.70	1.52-1.98

6.12 Dam 13

Dam 13 is located at Station 38+48 to 38+52 (4 linear feet) (**Figures 7** and **10 – Appendix A**) (**Photos 116**, **117**, and **118 – Appendix L**). POTESTA surveyed 262 linear feet of channel, including the backwater area behind Dam 13 (Reach 13) (**Photos 119**, **120**, **121**, and **122**). Dam 13 is located 241 feet downstream of Dam 12.

The dam was 33.9 feet wide and 3.2 feet high (**Table 17**). Dam 13 was constructed just below bankfull depth (**Figure 8 - Appendix I**). The width of the dam face was four feet across and the footprint of the structure in Turkey Creek was 135.6 ft^2 (**Photos 123** and **124**).

The bankfull slope was estimated at 0.0126 while the water surface slope was slightly higher (0.01293). The channel slope was measured at 0.01148 and was lower than the existing bankfull slope (**Figure 1 – Appendix I**). Riffle and run facets were discernible on the longitudinal profile (**Figure 1 –Appendix I**). The profile began at an upstream stable riffle. Some portions of the profile upstream of the dam were less discernible due to sediment deposition and backwater conditions. Based on slope and the longitudinal profile (bedform pattern), this section of Turkey Creek may have had a plane bed morphology which typically lack pools (Montgomery & Buffington 1997).

Figure 2 (**Appendix I**) depicts the estimated channel slope, bankfull slope, and water surface slope prediction upon the initial dam removal process. The change in channel slope was estimated at 0.00035 (0.035 percent). This slope change is minimal. Based on existing channel morphology and overall stability throughout the reach, downcutting upon removal of the dam is not anticipated. However, this reach should be observed after the first few bankfull events because existing downcutting was noted downstream of the dam (see XS4) (**Photos 125** and **126**). The BHR was moderate (1.46) indicating active incision.

The bankfull width upstream of the dam (XS1 – Station 38+67) was 37.5 feet with a depth of 1.65 feet (bankfull area 61.8 square feet) (**Figure 3 – Appendix I**). Based upon cross-sectional area and width and depth ratio, XS1 had aggraded and over widened due to the placement of Dam 13. Upon dam removal, it is expected that the cross-sectional area of the bankfull channel will decrease. Sediment deposition and embeddedness in the upstream portion of the Dam 13 study reach was moderate (**Photos 127** and **128**). Based on visual observations, it is suspected that bar formation had become more pronounced in the upstream portion of the reach.

An existing secondary channel was also present in the floodplain at Reach 13, as well as other recently formed and smaller secondary channels. Like the secondary channel adjacent to Dam 14, it is likely that the existing Dam 13 secondary channel intermittent in nature. The channel had bed and bank features as well as substrate. The newly developing secondary channels were identified upstream of the dam. These channels were poorly defined and relative small and were caused by the mainstem apparently adjusting to backwater impacts associated with Dam 13.

Foundation failure was not observed at Dam 13 (XS2 – Station 38+46 to 38+52) (**Figure 4 – Appendix I**); however, left and right bank abutment failures were developing. The channel upstream of the dam was already noted to be overwide. The widening of the channel can eventually contribute to abutment failure, even exacerbated it, due to flow accelerating around the edge of the dam during high flow events. The cross-sectional area of the scour pool was approximately 62.2 square feet (XS3 – Station 38+43)(**Figure 5 – Appendix I**), which was similar to the cross-sectional area of the pool surveyed in XS1 upstream of the dam (61.8 square feet).

The riffle or XS4 (Station 38+00) had a bankfull width of 30 feet and a depth of 2.07 feet (bankfull area 62.2 square feet) (**Figure 6 – Appendix I**). Based on regional curve data and observed exposed rooting depths, the area immediately downstream of the riffle was downcutting or beginning to incise (**Photos 125** and **126**). The entrenchment ratio of 3.66 which was slightly entrenched with a 14.5 width/depth ratio suggests that this portion of the study reach was a C channel. POTESTA believes that increased entrenchment ratio and decreased width/depth ratio may indicate that a successional shift to a less stable channel configuration of C to Gc to F stream type was occurring and would accelerate if Dam 13 were left in place. A shift from a C to G stream type shift would result in long-term, adverse effects on sediment supply (Rosgen 2006). Restoration efforts should focus on restoring stable dimensions that reflect a Bc to C stream type.

Using the Ridge and Valley regional curve for streams with a drainage area of 6.99 square miles (**Figure 7 – Appendix I**) bankfull width ranges from 26.20 to 32.68 feet for width, 1.52 to 1.98, feet for mean depth, and 48.02 to 54.14 square feet for cross-sectional area (**Table 18**). Based on the comparison of XS4 (riffle) and the regional curve, the downstream portion of Reach 13 falls outside the cross-sectional area and depth ranges predicted by the Ridge and Valley curve (**Figure 7 – Appendix I**). The channel was slightly deeper than the regional curve indicates and appears to have degraded.

The upstream and downstream views of the dam are shown on **Figure 8 (Appendix I)**. Stable banks were observed in the upstream and downstream view; however, the upstream vegetation along the lower portions of the floodplain had become inundated. Due to these conditions, bank stability and vegetative ground cover was poor upstream of the dam. Vegetation and bank stability along the right bank at and below the dam abutment was protected by rootwads; however, it is likely the banks will continue to erode around the cover due to active incision (**Figure 9 – Appendix I)**.

Minor amounts of large woody debris were noted in the floodplain and on the dam. Abundant amounts of coarse and fine woody debris from beaver activity was noted behind the dam. Stream dimension or bankfull measurements upstream of the dam were not consistent with the Ridge and Valley curve and would be considered widened. Some bar formation along the LDB was noted downstream of the dam (**Photo 129** and **130**).

Removal of Dam 13 should be completed from the right bank. Existing roadbed should be utilized (**Photos 131** and **132**). The structure should be released in a controlled manner with flow directed towards the center of the channel away from the developing abutment failures. At this time, POTESTA recommends that restoration efforts focus on the areas located upstream of the dam that are over widened and inundated that need to be stabilized and permanently vegetated to prevent further lateral instability and mass bank erosion (**Photo 133**). Additionally, the areas downstream of the dam that are downcutting should be stabilized and monitored. However, POTESTA recommends the reach be reevaluated prior to construction activities as high winter and spring flows may alter the existing condition and require further consideration.

It is important to not impact the historic secondary channel during dam removal activity. It is likely that these reaches would be considered jurisdictional and should be avoided. Upon removal of Dam 13, the recently formed secondary channels will require vegetation and potential grading to prevent the channel from widening further and reduce potential of mass erosion adjacent to the mainstem. Post-construction monitoring should be initiated after the first few storm events to evaluate the ongoing erosion on the right bank below the dam. If erosion rates are accelerated, remedial measures will be necessary. This may include instream structures to divert flow away from the right bank.

Once Dam 13 is removed, it is expected that the fine sediment (silts) will be mobilized by channel flow; however, successful vegetation establishment is vital to reducing the continued input of streambank erosion at the site. During flood events, both fines and woody debris would be deposited in the floodplain and be transported through the system.

Table 17
Dam 13 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Failure
13	33.9	3.2	4	38+48 – 38+52	6.99	Y

TABLE 18
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				Ridge and Valley Province Reference		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	62.2	30	2.07	48.02 – 54.14	26.20 – 32.68	1.52 – 1.98

6.13 Dam 12

Dam 12 was located at Station 41+16 to 41+20 (4 linear feet) (**Figures 7** and **10 – Appendix A**) (**Photos 134** and **135**). POTESTA surveyed 403 linear feet of channel, including the backwater area behind Dam 12 (Reach 12) (**Photos 136**, **137**, and **138**). Dam 12 was located 274 linear feet downstream of Dam 11.

The dam was 32.8 feet wide and 2.5 feet high (**Table 19**) (**Photos 139** and **140).** POTESTA noted that the dam was constructed just above bankfull elevation. The width of the dam face was four feet across and the footprint of the structure in Turkey Creek was 131.2 ft^2.

The bankfull slope was estimated at 0.0115 while the water surface slope was lower (0.0091). The channel slope was measured at 0.0092 which was lower than the existing bankfull slope (**Figure 1 – Appendix J**). The profile began at an upstream stable riffle; however, the upstream portion of the reach was less defined which was attributed to sediment deposition and backwater conditions. However, riffle, run, pool, and glide facets were discernible on the longitudinal profile (**Figure 1 – Appendix J**).

Figure 2 (Appendix J) depicts the estimated channel slope, bankfull slope, and water surface slope prediction upon the initial dam removal process. The change in channel slope is estimated at 0.00096 (0.096 percent). The slope change predicted for this study reach was the second highest of the Turkey Creek dams; however, this change is less than one percent. Due to existing incision or downcutting, this reach will potentially require grade control and bank stabilization techniques. Sediment deposition upstream of the dam was minor to moderate due to the development of a secondary channel or avulsion. This site is at risk for severe bank erosion and sediment deposition downstream.

The bankfull width upstream of the dam (XS1 – Station 41+54) was 45.2 feet with a depth of 1.27 feet (bankfull area 57.6 square feet) (**Figure 3 – Appendix J**). Based upon cross-sectional area and width/depth ratio XS1 had aggraded and over widened due to the placement of Dam 12. Upon dam removal, it is expected that the cross-sectional area of the bankfull channel will decrease. Sections of stream above the dam will need to be stabilized and permanently vegetated to prevent further lateral instability and mass bank erosion. Additionally, the sediment deposition and embeddedness in the upstream portion of the Dam 12 study reach was moderate to extensive and bar formation has become more pronounced in the upstream portion of the reach.

Recently developed secondary channels were also present at the site (**Photos 141 – 152**). It is likely that, during high-flow events, water will distribute across the floodplain and these channels can migrate naturally to dissipate energy and increase exchange of nutrient and material between aquatic and riparian habitats. While these secondary channels carry flood waters during high-flow events, their presence at Dam 12 could lead to an avulsion if the dam were left in place. These channels were caused by the mainstem adjusting to backwater impacts associated with Dam 12. Upon removal of Dam 12, these recently formed secondary channels will require vegetation and potential grading to prevent the channel from widening further and reduce potential of mass erosion adjacent to the mainstem.

No foundation failure was present at Dam 12 (XS2) or abutment failures were noted (**Photo 153**, **154**, and **155**) (**Figure 4 – Appendix J**). As noted above, this structure was constructed above bankfull elevation, the channel upstream of the dam was over widened and will eventually contribute to abutment failure or avulsion along the right bank. The cross-sectional area of the scour pool, XS3 (Station 40+84), was approximately 50.3 square feet (**Figure 5 – Appendix J**), which was similar to the cross-sectional area of the pool surveyed in XS1 upstream of the dam (57.6 square feet).

The entrenchment ratio of 2.74 with a 28.27 width/depth ratio suggests that this portion of the study reach was a C channel. POTESTA believes that increased, slightly entrenchment ratio and decreased width/depth ratio may reflect a potential successional shift to a less stable channel configuration of C to Gc to F stream type if Dam 12 were left in place. A shift from a C to G stream type shift would result in long-term, adverse effects on sediment supply (Rosgen 2006). The restored or stable dimensions should reflect a Bc to C stream type.

The riffle or XS4 (Station 40+66) had a bankfull width of 33.6 feet and a depth of 1.19 feet (bankfull area 40 square feet),(**Figure 6 – Appendix J**). Using the Ridge and Valley regional curve for streams with a drainage area of 6.95 square miles (**Figure 7 – Appendix J**), bankfull width ranges from 26.14 to 32.60 feet for width, 1.51 to 1.97 feet for mean depth, and 47.83 to 53.93 square feet for cross-sectional area (**Table 20**). Based on the regional curve and observed exposed rooting depths, the area immediately downstream of the riffle was downcutting or beginning to incise. The comparison of XS4 (riffle) and the regional curve finds that the lower portion of Reach 12 falls outside the cross-sectional area, width, and depth ranges predicted by the Ridge and Valley curve (**Figure 7 – Appendix J**). The channel was wider than the regional curve indicates and appears to have degraded.

The upstream and downstream views of the dam are shown on **Figure 8 (Appendix J)**. Stable banks were observed in the upstream and downstream view; however, the upstream vegetation along the lower portions of the floodplain had become inundated. Due to these conditions, bank stability and vegetative ground cover was poor upstream of the dam. Vegetation and bank stability along the right bank at and below the dam abutment were protected by root wads, however, it is likely the banks will continue to erode around the cover due to active incision (**Figure 9 – Appendix J**).

Dam removal efforts should be initiated on the right bank at Dam 12. As noted above, this area was littered with secondary channels some of which contain substantial flow. As a result, the area around Dam 12 will likely be damp or wet and extra care will be required. Supplemental support in the form of timber riprap or prefabricated equipment mats may be necessary. The dam should be disassembled in a manner that moves flow towards the center of the channel. The banks will require vegetation and stabilization. Instream structures are not recommended at this time but this reach, like the others, should be reevaluated prior to construction.

The substrate upstream of the dam was mixture of silt and embedded gravel, cobble, and boulder. Backwater influence or sedimentation upstream of the dam was moderate. Large woody debris was noted in the floodplain and on the dam (**Photos 156**, **157**, **158**, and **159**). Abundant amounts of coarse and fine woody debris from beaver activity was noted behind the dam. Some bar formation along the LDB was noted downstream of the dam (**Photo 160**). Once Dam 12 is removed, it is expected that the fine sediment (silts) will be mobilized by channel flow. The existing BHR was 1.0; therefore, it is anticipated that, during flood events, both fines and woody debris would be deposited in the floodplain and be transported through the system.

Table 19
Dam 12 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Spacing	Failure
13	32.8	2.5	4	41+16-41+20	6.95	181	N

TABLE 20
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				**Ridge and Valley Province Reference**		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	40	33.6	1.19	47.83 – 53.93	26.14 – 32.60	1.51 – 1.97

6.14 Dam 11

Dam 11 was located at Station 43+94 to 44+00 (6 linear feet) (**Figures 7 and 10 – Appendix A**) (**Photos 161**, **162**, **163**, **164**, and **165 – Appendix L**). POTESTA surveyed 300 linear feet of channel, including the backwater behind Dam 11 (Reach 11) (Photos **167**, **168**, and **169**).

The dam was 35.4 feet wide and 2.8 feet high (**Table 21**). The dam was constructed just below bankfull. The face of the dam was six feet across and the footprint of the structure in Turkey Creek was 212.4 ft^2.

The bankfull slope was estimated at 0.0098 while the water surface slope was higher (0.011). The channel slope was also measured at 0.0083 (**Figure 1 – Appendix K**). Riffle, run, pool and glide facets were discernible on the longitudinal profile (**Figure 1 – Appendix K**).

Figure 2 (**Appendix K**) depicts what the estimated channel slope, bankfull slope, and water surface slope predicted upon the initial dam removal process. The change in channel slope was estimated at 0.00099 (0.099 percent). The slope change predicted for this study reach was the highest of the Turkey Creek dams in this document. Due to the slope change, Reach 11 may potentially require grade control and bank stabilization techniques. Sediment deposition upstream of the dam was moderate and also influenced by various levels of beaver activity. During an earlier visit to Dam 11 in 2014, beaver increased the height of the dam (**Photos 170**, **171**, **172**, and **173**). During later visits, only debris remained (**Photo 174**).

The bankfull width upstream of the dam (XS1 – Station 44+15) was 37.4 feet with a depth of 0.94 feet (bankfull area 35.2 square feet) (**Figure 3 – Appendix K**). Based upon cross-sectional area and width/depth ratio, XS1 had aggraded and had become over widened due to the placement of Dam 11. Upon dam removal, it is expected that the cross-sectional area of the bankfull channel will decrease. Inundated sections of stream above the dam will need to be stabilized and permanently vegetated to prevent further lateral instability and mass bank erosion. Additionally, the sediment deposition and embeddedness in the upstream portion of the Dam 11 study reach was moderate (**Photos 175** and **176**).

Dam height was measured from the toe. There was no foundation failure at Dam 11 (XS2); however, the right abutment had failed (**Figure 4** – **Appendix K**). During high-flow events (greater than bankfull), waters were accelerating around the abutments of the dam which resulted in eroding of the RDB (**Photos 177**, **178**, **179**, and **180**). This was compounded by the lack of vegetation and disturbance during construction. The cross-sectional area of the scour pool, XS3 (Station 43+89), was approximately 75 square feet (**Figure 5 – Appendix K**), which was larger than the cross-sectional area of the pool surveyed in XS1 upstream of the dam (35.2 square feet). The riffle or XS4 (Station 43+44) had a bankfull width of 33 feet and a depth of 1.55 feet (bankfull area 51.2 square feet) (**Figure 6** – **Appendix K**).

The entrenchment ratio of 1.81 with a 19.49 width/depth ratio suggests that this portion of the study reach was classified as a B to Bc channel type. Limits were used on this cross section to reflect bankfull conditions on the mainstem. A small, recently developed secondary channel was included in the survey at XS2 and XS4. This area of the survey appears to be remnant of lateral instability from both the beaver dam and Dam 11 (**Photos 180**, **181**, **182**, **183**, **184**, and **185**). With the beaver dam, water only flowed through this area during flows greater than bankfull elevation. Regardless, this area will require grading and permanent vegetation to prevent further channel widening and mass erosion.

Using the Ridge and Valley regional curve for streams with a drainage area of 6.87 square miles, bankfull width ranges from 26.01 to 32.44 feet for width, 1.51 to 1.96 feet for mean depth, and 47.43 to 53.49 square feet for cross-sectional area (**Table 22**). Based on the comparison of XS4 (riffle) and the regional curve, the reach falls outside the cross-sectional area range predicted by the Ridge and Valley curve (**Figure 7 – Appendix K**). The channel was wider than the regional curve indicates; however, cross-sectional area and mean depth were within predicted ranges.

The upstream and downstream views of the dam are shown on **Figure 8 (Appendix K)**. Stable vegetation was observed in the downstream view; however, the upstream vegetation along the lower portions of the floodplain had become inundated. Beaver activity was also noted immediately upstream of Dam 11. Due to the widened channel and decreased bank stability, vegetative cover was marginal to poor upstream of the dam. The substrate upstream of the dam was silt, gravel, cobble, and boulder.

Dam removal efforts should be initiated on the right bank at Dam 11. As noted above, this area contains secondary channels and, even if beaver activity is minimal, these areas could be damp or wet and extra care will be required. Supplemental support in the form of timber riprap or prefabricated equipment mats may be necessary. The dam should be disassembled in a manner that moves flow towards the center of the channel. The banks will require vegetation and stabilization. Instream structures are not recommended at this time but this reach, like the others, should be reevaluated prior to construction.

Once Dam 11 is removed, it is expected that the fine sediment (silts) will be mobilized by channel flow; however, successful vegetation establishment is vital to reducing the continued input of streambank erosion at the site. Based on existing data and visual observations, it is likely that, during flood events, both fines and woody debris would be deposited in the floodplain and be transported through the system.

Table 21
Dam 11 Measurements

Dam	Width	Height	Length	Stationing	Drainage Area	Failure
11	35.4	2.8	6	43+94 – 44+00	6.87	Y

TABLE 22
Turkey Creek and Ridge & Valley Regional Curve Comparison

Stream Channel Characteristics						
Turkey Creek				Ridge and Valley Province Reference		
	A_{bkf}	W_{bkf}	D_{bkf}	A_{bkf}	W_{bkf}	D_{bkf}
XS4 - Riffle	51	33	1.55	47.43 – 53.49	26.01 – 32.44	1.51 – 1.96

7.0 DISCUSSION

In the press release from the USEPA regarding the consent decree for this project, it stated that the structures placed in Turkey Creek reduced water quality, changed water flow, reshaped the stream, disrupted fish passage, and caused sediment build up (USEPA 2015). The discussion below addresses these issues as well as other pros and cons associated with dam construction and removal as it relates to the structures in Turkey Creek. It should be noted that the landowner placed the structures in Turkey Creek with the intent to improve fisheries. These structures are being removed as per the consent decree. Dam removal as a result of legal proceedings is not unusual and Bowman (2002) found that, while sometimes dam removal is voluntary, many dam removal decisions are the result of legal proceedings, either as a formal outcome or through negotiated settlement. In this instance, there is likely environmental benefit to remove these structures and pursue improvement of fisheries using other measures.

7.1 Classifying and Regulatory Oversite

Dams are structures that are typically constructed to retain water and modify its magnitude and timing downstream. Dams also come in a variety of sizes, from the largest, which is just over 1,000 feet to smaller ones that are less than 2 meters. The dams in Turkey Creek are very similar to low-head run-of-river structures that can be found throughout Europe and several states like Pennsylvania and Wisconsin where the structures are used for small hydropower schemes (Robson et al. 2011). The term "low-head" typically refers to height, with low-head structures usually being less than 10 feet high (Elverum and Smalley 2012). Often, low-head dams have no gates or water control devices. Run-of-river dams differ from storage dams in that they have small hydraulic head and storage volume, short residence time, and little or no control over the water-release rate (USEPA 1993).

The number of small dams, like those in Turkey Creek, is believed to be underestimated in national inventories. In 1996, there were approximately 75,000 large dams in the United States (Orr et al. 2004). The inventory does not contain many of the smaller dams which have been estimated in the 2,000,000 structure range. Large dams, those in Section 10 waters, are typically regulated by the USACE. Smaller dams, or those not regulated by the USACE, may be regulated by state agencies (Vedachalam and Riha 2014).

In West Virginia, dams that do not fall under the USACE's jurisdiction can be regulated by the WVDEP under the Dam Control and Safety Act. Structures that meet the State's definition of a dam, 25 feet or more in height and impounding 15 or more acre-feet or 6 feet in height and impounding 50 or more acre-feet, must comply with the regulatory requirements under the Act and the States Dam Safety Rule (47 CSR 34). The structures in Turkey Creek, both individually and cumulatively, are too small and do not have the height or the storage volume to trigger dam safety requirements. The complete definition of a "dam" may be found in the Dam Control and Safety Act - W. Va. Code 22-14-3(f), and in the Dam Safety Rule (47CSR34-2.12).

7.2 Ecological Effects

There is an abundant amount of information regarding the ecological effect of dam construction, but the response of fish, benthic macroinvertebrate, and vegetative communities up and downstream of dam removal projects has been limited (Doyle et al. 2003; Woodward, et al. 2008), particularly run-of-river reservoirs (Ahearn and Dalgren 2005). Regardless, current research suggest ecological response to dam removal is a trade-off that must be conducted on a case-by-case basis involving site-specific conditions such as the size, location and configuration of the dam and the nature of the resident biota (Poff and Hart 2002). Dams create a long, flat water surface marked by an abrupt drop. After a dam is removed, water levels and channel positions more closely resemble the original channel morphology and the new longitudinal profile can cause changes in the distribution and structure of aquatic communities (Gregory et al. 2002).

7.2.1 Fish

As noted in the introduction, the structures in Turkey Creek were put in place in an effort to improve fisheries. There are several long stretches in Turkey Creek that appear to be primarily plane:bed which would not promote pool development. With the intent of providing more heterogeneous habitat, forced pools were created by placing the low-head structures in Turkey Creek. While well intentioned, the presence of dams can result in a disruption of longitudinal connectivity in a river system (Poulos et al 2014). Changes in the frequency and/or duration of drought and flood episodes can be influenced by dams which can influence population dynamics, including trout species (Alonso-González et al. 2008).

Unfortunately, the scientific literature on the impacts of fragmentation that can result from series of small, low-head barriers is limited. Therefore, in some instances, the more comprehensive body of evidence from larger structures, is used to infer impacts. In general, it is assumed that, since both big and small dams have the same structural elements, small structures have the potential to pose threats to aquatic ecosystems by disrupting sediment dynamics, altering riverine biodiversity, compositing and abundance, reducing access to feeding, spawning, and nursery habitats, and blocking or delaying the movements of migratory fish.

Of particular concern in Turkey Creek are Salmonids, the fishery the structures intended to protect. Research, primarily in Europe, has found low-head barriers can be barriers to fish movement. A summary by Snuffer (2011) indicates that radio-tagging studies have found fish reluctant to move downstream over or through structures and will often return upstream when confronted by a weir. This included studies with brown trout who, when prevented from entering a spawning area (due to a physical barrier), were reluctant to access alternate tributaries, highlighting their selective behavior. For salmonids Snuffer (2011) reported that even slight modification to local habitats can influence the suitability for certain species and this can lead to changes in fish species assemblages. While the structures on Turkey Creek do not exceed six feet, the depth downstream (and upstream) of potential barriers influences passage success. Even short vertical sills can be insurmountable for salmonids if there isn't sufficient water depth downstream.

In addition to the salmonids, other resident fish species are likely present in Turkey Creek. The effects of lowhead dams and their removal on resident fish species has not been well documented. A study in Maine found rapid recolonization of fish species upstream of a dam post removal (Gardner et al 2013).

Benthic Macroinvertebrates

Research regarding flushing of sediments behind reservoirs found that benthic communities downstream of flushing operations were severely impaired; however, recovery to preexisting conditions occurred in a few months (Espa et al. 2013).

Researchers in Wisconsin (Stanley et al. 2002) studying removal of three dams in series found substantial difference between the benthic communities in unimpounded and impounded reaches pre-dam removal. This is not surprising based on changes in flow and substrate that were likely present. However, these researchers found that the dams acted as barriers to some invertebrates and fish and not to others. Similarly, the impounded reaches represented inhospitable habitat for some, but not all lotic species. This study demonstrated the lack of understanding of the ecological consequences of low-head dams and the changes that can be found in upstream communities due to the presence of even small structures. This study also found that recovery of benthic and fish communities upstream of the dams were rapid.

The potential impacts to the benthic macroinvertebrate community in Turkey Creek are expected to be minimal. Further, monitoring will be necessary but it is anticipated that little change will occur in the benthic macroinvertebrate population as a result to the removal of the dams.

Sediment

As noted, after dam removal it is anticipated that sediments will be dispersed and/or incorporated into the new bed created by stream flow in Turkey Creek. It is assumed that the change in the longitudinal profile will be minimal as the vertical relief of the sediment deposits does not create as much potential for abrupt vertical erosion. Sediments upstream of the dams were heterogeneous in nature, not solely composed of fine-grained sands. No armoring was noted.

A literature based review of sediment effect from small dam removal found that, while often advocated, very few rigorous studies have been completed on the consequences of dam removal and sediments (Bushaw-Newton et al. 2002; Burroughs 2007; Roberts et al. 2007). It has been estimated that only about five percent of the dams removed in the past two decades were accompanied by published reports or studies, which is limiting, as each one is a lost research opportunity. While removal of small dams may be beneficial as it can restore natural flow, there is also the potential for large volumes of sediment being released by flushing which may have a negative effect on downstream communities. At a minimum, trapped sediments when mobilized can muddy waters downstream. Thus dam removal can be both beneficial and detrimental, depending on the local setting and scale.

In Turkey Creek, it has been observed that the dams have very low trapping efficiency (and capacity) and have not retained large amounts of fine-grained sediments. The material present behind Dams 11 - 20 is an estimated 2,800 m^3 combined; however, the movement of some of these materials and its downstream transport is dependent on channel-forming discharge events (bankfull flows) (Kondolf 1997). The occurrence of these flows cannot be depicted. Regardless, because material is not compacted and active transport is still occurring it may only be a short period of time before bedload material is redistributed post construction in downstream reaches.

The studies regarding small dam removal in the literature also differ in that many have been in place for decades so the amounts of material lodge behind these dams far exceeds the amounts potentially found in Turkey Creek. For example, Ashley et al. (2006) studied the removal of a dam in Manatawny Creek in Pennsylvania that was a low-head run-of-river structure; however, this feature had been in place since the 1750s with sediment volumes estimated at 10,300 m^3 and a residence time of approximately 1.6 hours. Comparatively, the estimated accumulated sediment behind Dams 11, 13, 14, 17, and 19 are almost 100-fold less than this volume and these dams have little or no residence time which makes direct comparisons difficult.

In 2003, a study was completed on a run-of-river removal in Murphy Creek in California (Ahern and Dahlgren 2005). This study had similarities to Turkey Creek as the watershed approximately 12 km^2, the structure had only been in place since the 1970s, and the dam that was removed fell below a series of other run-of-river dams. However, the structure here was slightly larger, approximately 3 meters high, and elongated so more sediments were trapped behind the dam. As expected, total suspended solids concentrations were higher post-dam removal and, while these concentrations seemed to be independent of flow conditions, most of the sediments were transported during storm events. Most of the sediment excavation occurred in pools and in the lower section of the reservoir where a knickpoint migrated upstream until reaching bedrock control. Three months post removal there was little remaining reservoir sediment in the upper portion of the former impoundment. Post one year, the increase in sediment transport was no longer evident.

The most critical variable for sediment removal of the dams in Turkey Creek is slope. It is anticipated that the minor change in slope associated with the removal of each dam will result in localized higher velocities as well as shear stress and stream power; however, observations indicate that the amount of fine-grained sediment to be entrained will be limited. A generous portion of the material behind the dams is gravel and cobble sized material and significant transport of these materials should only be expected at higher flows (Bushaw-Newton et al. 2002). This is in contrast to a lot of the literature based evaluations where dam removals are accompanied by immediate sediment transport due to a dominance of silts and clays in the impoundments; however, in Turkey Creek, visual evidence indicates that these materials are actively transported during the rising leg of even small storm hydrographs and the structures in place are not entirely impeding the movement of this material. Part of the reason for the continuing transport of fine-grain material may be the fact that the structures are placed at or below bankfull. Consistent with the literature, structures built in areas with low slopes with the crest elevations lower than the adjacent floodplain (mostly confined within the river channel) have flow regimes that are unlikely to be altered and sedimentation behind the dam is likely to be insignificant (Wan et al. 2015). At structures that have failed, there is no deposition and, therefore, transport is ongoing.

Turkey Creek also differs from other dam removal locations with regard to the imbalance that often occurs between fluvial sediment supply and transport capacity. Typically, fine sediments build up behind dams and dam removal results in oversupply, which causes sedimentation downstream (Draut and Richie 2015). In Turkey Creek, while there is some material available for transport, the dams in -series have likely created a supply deficit. The structures allow very fine-grains to continue through the system and larger particles, the bedload, is in effect limited due to the lack of input from upstream. If left in place, it is likely that the dam will result in small reaches that are “hungry.” Upstream of the dams, the bedload will move until it is deposited behind the dam. Downstream, the water discharging across the face of the dam has the power to transport bedload material but none are present (Koldolf 1997). If left in place it is likely that erosion would begin to occur downstream as the stream tries to regain sediment equilibrium (Bednarek 2001). As noted, upon dam removal, there may be temporary increases in fine material transported downstream; however, it is anticipated that, after several storm events, sediment equilibrium should be restored.

This concept is also noted in dams of similar size in a comparative study in Pennsylvania and Maryland. The study sites had notably higher D_{50} values below the dams but the percentage of boulders and bedrock remained unchanged (Slalack et al. 2009). This study also indicated that small dams like those on Turkey Creek, that exhibit features like inerodible bedrock, relatively immobile boulders, well-vegetative and cohesive banks, and low rates of bed material supply and transport will experience limited long-term geomorphic changes post-dam removal.

The change in slope at the dam site is not expected to result in substantial modification of slope both upstream and downstream due to the minor nature of the change and the expected timeframe for the channel to return to equilibrium. If one considers the Channel Evolution Models ("CEM"), the scenario in Turkey Creek is one that currently would indicate high potential for restoration success (Pizzuto 2002). Prior to dam construction, it is likely that the reaches described above were stable. The existing (and historic) system appear to be Bc or C channels in nature and the channel had access to the adjacent floodplain. Due to dam placement, some locations are moving towards F channel types. State II of the CEM is disturbance. Here it would be the removal of the dam and increase stream power through the section is expected to have some downcutting, particularly through the sediments deposited behind each dam (becoming an F stream). Keeping in mind that the existing site is still connected to the historic floodplain, the later steps to the CEM are not expected to occur and new floodplain formation is unlikely. Limitations at several of the sites, like bedrock control, will help to stabilize the system and bring it to equilibrium. Changes in slope are also limited (**Table 23**). If removal occurs in the near future, it is theorized that the system, instead of moving through the sequence, will reset and remain Bc to C as appropriate. To enhance this effort, it may be necessary to do work along streambanks where erosion and inundation has occurred, but these efforts are minor compared to having to adjust to a floodplain at a new level.

Table 23
Pre- and Post-Construction Slopes in Turkey Creek – Dams 11 Through 20

Dam	Channel Slope		Water Surface		Bankfull Channel	
	Pre-Construction	Post-Construction	Pre-Construction	Post-Construction	Pre-Construction	Post-Construction
11	0.00828	0.00927	0.01077	0.01079	0.00980	0.01058
12	0.00922	0.01018	0.00912	0.01023	0.01153	0.01070
13	0.01148	0.01183	0.01293	0.01223	0.01263	0.01044
14	0.01068	0.01122	0.00834	0.01159	0.00971	0.00991
15	0.00923*	0.00923*	0.00741	0.01022	0.00921	0.01073
16	0.01565	0.01525	0.01555	0.0159	0.01419	0.01346
17	0.01558	0.01582	0.01537	0.01353	0.01314*	0.01314*
18	0.01397	0.01356	0.01666	0.01582	0.01731	0.01667
19	0.01231	0.01246	0.01145	0.01305	0.01263	0.01323
20	0.00725	0.00884	0.00782	0.00772	0.00919*	0.00919*

*Estimated No Change in Slope

Often, scientists look to models to make determinations regarding ecological effect. It is likely that some components of dam removal in this system could be modeled on a minor scale; for example, a model called DREAM (dam removal express assessment models) can model sediment transport. However, it is important to note that dam removal can initiate a multitude of abiotic and biotic changes that differ at temporal and spatial scales. Each dam site is unique based not only on dam size, but watershed setting and condition. Effective prediction with any level of certainty regarding all factors associated with dam removal effects is, in no uncertain terms, impossible. This is not to debase the potential use of models, such as the USACE's Hydrological Engineering Centers River Analysis System (HEC-RAS), which can be used evaluate floodplain issues, but to highlight that, even with some level of research, available dam removal impacts are site specific and must be considered on a case-by-case basis (Vedachalam and Riha 2014). Ultimately, there will always be a level of uncertainty as the mobility and associated transport are flow dependent with the most material transported during floods (Kondolf 1997) and the ability to predict this process is limited as no one knows what the weather holds (Doyle et al 2003a).

Other Physicochemical Parameters

Dam removal can result in changes in water quality and nutrient transport as well as mobilization of metals or other contaminants downstream (Orr et al. 2006; Roberts et al. 2007). Temperature or thermal consequences of dam removal have not been well evaluated; however, it is reasonable to assume that water temperatures post-dam removal would return to a close semblance of pre-dam condition if the riparian corridor remains intact (Bartholow et al. 2005). In Turkey Creek, temperature deviations have not been evaluated but the resonance time at the dams is thought to be minimal, therefore, temperature changes were not considered among the dams potential effects. Therefore, dam removal should not result in any thermal changes in Turkey Creek. This is consistent with other low-head dam removal projects (Stanley et al. 2002). Other water quality parameters, such as dissolved oxygen, pH and specific conductance, have not been considered as routine water quality evaluations found no changes in these parameters upstream to downstream.

Nutrient transport in Turkey Creek is difficult to predict. Nutrient spiraling is often used to describe nutrient transport and uptake in system and the presence of dams modifies this "spiral" (Orr et al. 2006). If one considers nitrogen ("N") and phosphorus ("P") with channel form and the degree of sediment-water contact used to evaluate N and sediment transport for P (Stanley and Doyle 2002), only minimal change in Turkey Creek is anticipated. As noted above in the discussions regarding each dam, the wetted perimeter at the dams has increased, reducing sediment-water contact; however, these changes are not substantial and, post-dam removal, the wetted perimeter is expected to be similar to the pre-dam condition. With regard to sediment transport, smaller material is still being actively transported throughout this system and, post-dam removal, it is anticipated to achieve equilibrium rapidly. However, it should be noted that transport is not a function of wetted perimeter alone and is influenced by other components of the bottom sediments (Velinsky et al. 2006). Further, each of the dams in Turkey Creek vary, so their individual effect on nutrient transport will also be different.

There are no known sources of contaminants upstream of the structures in Turkey Creek; therefore, it is unlikely that the release of sediments from behind the dams in Turkey Creek will result in entrainment of contaminated sediments.

Vegetation and the Riparian Zone

As noted in the discussions above, sediment retention and resonance time in Turkey Creek are minimal. This is fortunate as key changes in the physical environment that influence vegetation have not occurred. Specifically, while portions of the riparian corridor directly upgradient of the dams has been inundated with water, large portions of the low bank and floodplain were not submersed. Vegetative losses appear to be limited to plants that were physically inundated by waters and extent of these effects is limited to the near bankfull elevations and only directly upgradient of the structures. The flow regimens change in this area are localized. While there is pooling behind the dam due to the change in water surface elevation, the pool behind the structure has not promoted the development of more hydrophilic plant growth. Overall, changes in hydrology around the dam are not believed to have been substantial enough to alter the type of riparian vegetative community present along Turkey Creek to those that are more sensitive to water table declines. Therefore, changes to the riparian community that could result from lack of inundation are not anticipated.

Systems with lower sediment supply, like the dams in Turkey Creek, any changes in vegetation colonization may result in few downstream changes and relatively simple upstream changes (Shafroth et al. 2002). While riparian plantings may be necessary in areas directly adjacent to the channel (due to the loss of vegetation in these areas), extensive planting is not anticipated. Substrate can impact post-dam colonization and its species composition; however, in Turkey Creek, select species will be utilized versus natural succession. Species selected for post dam removal planting should be species that help stabilize banks both upstream and downstream of the dam sites which may reduce overall sediment transport. Since revegetation is recommended, but most of the riparian zone is intact, species should focus on fast growing early successional native species that will stabilize banks, reduce invasive species and promote long-term success.

Riparian zones can be naturally stochastic, sometimes undergoing large changes in short timeframes. Large scale storms and associated flooding events cause both erosion and deposition in the riparian corridor which can cause burst of recruitment immediately following large scale disturbance (Braatne et al. 2008). As noted above, it is likely that Turkey Creek remains connected to the floodplain and will continue to benefit from flooding events post-dam removal.

Summary

Evaluation of ecological response to dam removal is a trade-off that must be conducted on a case-by-case basis involving site-specific conditions such as the size, location and configuration of the dam and the nature of the resident biota. Further, there are three areas to consider, within the impounded area, downstream from the dam, and the free-flowing areas farther upstream (Hart et al 2002). A substantial ecological response to dam removal is not anticipated in Turkey

Creek as the dams are young, comparatively, and the system was stable prior to dam construction.

8.0 CONCLUSION

Throughout this process, it is important to remind oneself that, while dam removal is often assumed to be inherently beneficial, there is a profound lack of data on the actual effects of dam removal. To compound this issue, Turkey Creek contains relatively new structures that are small in scale, but placed in series. As a result, the removal of dams in Turkey Creek is being done without extensive empirical data to support the conclusion that the removal of the instream structures will have an overall ecological benefit. Instead, we are guided by regulation, where these structures were placed in Turkey Creek, without authorization, which is a violation of the CWA and, therefore, removal is required. Fortunately, the brevity of time (the structures have been in place) and portions of bedrock control throughout these reaches will likely play a role on the overall effect of dam removal.

The first step of dam removal will be a multistage process geared toward the preliminary restoration of Turkey Creek. POTESTA believes that additional monitoring following the removal of the dams from Turkey Creek will require further monitoring and management after the dam removal. Adaptive management will play a key role. POTESTA believes that, due to existing dam failures at Dams 20 through 11, much of the sediment trapped behind the dams is not as extensive as originally believed prior to stream surveys.

Developing and implementing dam removal and stream bank stabilization measures for the impacted stream would be used to offset impacts to aquatic resources associated with the individual dams. This document contains preliminary restoration measures and plans for dam removal. Please note that these designs are not construction grade. Minor modifications may be required during final construction to accommodate onsite conditions.

Once each dam is removed, it is expected that the fine sediment (silts) will be mobilized by channel flow. While potential habitat quality may be impaired temporarily, the effects are expected to be short-lived in terms of sediment exposure. With decreased streamflow magnitude due to multiple dams, each study reach reflects some level of decreased sheer stress, stream power, and sediment transport. The consequences resulted in minor to moderate sediment deposition, aggradation, accelerated bank erosion, channel widening, and successional shift from a stable B/Bc stream type to G and F stream types. Sediment deposition point bars and side bars were minimal between Dams 20 and 11, but increased in intensity as the survey moved upstream where dams were closest together (181 to 274 linear feet). Debris and channel blockage have been present in the past due to beaver activity; however, the majority of large woody debris was located within the floodplain and not within the bankfull channel. Channel widths upstream of each dam were generally widened and would be considered to be aggrading, with the exception of Dam 20 (attributed to extreme foundation failure). Study reaches downstream of Dams 12, 13, and 14 were actively incising.

Prior to longitudinal survey, the level of sediment deposition and embeddedness upstream of each dam was perceived to great. However, after completion of each survey, POTESTA concluded that aggradation and bank instability were generally localized. POTESTA believes that the dams have not been instream long enough to cause permanent impairment and that each structure should be removed as soon as possible. Upon removal, sediment will be mobilized and transported downstream and deposited within the floodplains of Lower Turkey Creek.

Changes in channel morphology are driven by transport and storage of the coarser material in a system (Leopold, 1992). Lower Turkey Creek was dominated by large boulder and cobble with moderate to expansive floodplains. With a single dam, little or no long-term effects associated with sediment from dam removal would be expected, however, with 10 dams requiring removal so closely together, adaptive management/monitoring is imperative. The stream channel immediately upstream of some dams were widening; however, due to dam failures at certain locations, this condition was less pronounced.

POTESTA believes that, once the dams are removed, that each dam study reach should be monitored for bank instability or extreme degradation or aggradation. It is paramount that the stream banks from the dam to the backwater area be stabilized and that areas disturbed by dam removal activity also be stabilized and vegetated to prevent further bank erosion and lateral instability. Prior to and after dam removal, each cross section and longitudinal profile should be monitored. Each cross section was surveyed once; however, due to potential over-winter changes, POTESTA suggests monitoring these cross sections before and after dam removal. POTESTA recommends riffle and pool substrate characterizations and sieve analysis before and after dam removal to monitor sediment transport that could negatively influence Lower Turkey Creek (Water Resources Research, 2003).

Following dam removal, Turkey Creek should be monitored for decreased cross-sectional area at riffles, increased bar formation or sedimentation in pools and riffles (Howard,1982), especially the reaches downstream of each dam removal. The effects of dam removal are expected to be short lived. Removal should produce a substantial improvement in habitat quality, with only minor and short-lived deleterious effects in terms of sediment exposure upstream and deposition downstream of the dam. As no construction information has been provided, it is unknown how each dam was constructed within Lower Turkey Creek. Each dam removal should be monitored by a stream restoration professional to ensure that a grade control structure is not necessary within the footprint of the dam removal itself.

In addition, areas cleared or disturbed during dam construction should be investigated for invasive species. Stream restoration for each reach should include management of *Multiflora rosa*, *Elaeagnus umbellata*, *Lonicera* sp., *Ligustrum vulgare*, *Alliaria petiolate*, *Barberis thungergii*, *Polygonum cuspidatum*, *Microstegium vimineum*, and other listed invasive species. Invasive species can out compete native and newly-planted vegetation utilized in the planting plan. Native alternatives should be incorporated in the planting plan in addition to adaptive management. Slight to moderate presence of invasive species were noted during field surveys.

One of the goals of this project is to remove the structures during the late summer/early fall low-flow conditions. This effort will require regulatory approval. A Notice of Intent must be filed with the WVDEP - Division of Water and Waste Management for storm water associated with construction activities. While the total footprint of disturbance associated with the proposed removal of structures may not exceed one (1) acre, the activity may result in minor discharges of sediment-laden waters when each structure is breeched. The proposed effort will also apply for a Stream Activity Permit once a determination has been made with regard to regulatory approvals at the federal level.

9.0 CLOSING

This report was prepared at the client's request using data developed for or provided by Neely & Callaghan and POTESTA. The scope of this study was mutually devised by POTESTA and the client and is limited to the specific project, location, and time period described herein. The scope of services and report represent POTESTA's review of the sites proposed for restoration and POTESTA's understanding of site conditions as provided by others using the methods specified.

POTESTA assumes no responsibility for information provided or developed by others or for documenting conditions detectable with methods or techniques not specified in the scope of services.

Sincerely,

POTESTA & ASSOCIATES, INC.

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Attachments

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